[redacted]

NASA TECHNICAL MEMORANDUM

NASA TM X-52146

NASA TM X-52146

To ...
By auth...
Changed ...
Classifi...
Scientific ...

NASA AGENA D MISSION CAPABILITIES AND RESTRAINTS CATALOG

[redacted]

(ACCESSION NUMBER)	(THRU)
119	2

Lewis Research Center
Cleveland, Ohio

VOLUME I

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION · WASHINGTON, D.C. · 1965

[redacted]

C66-2583

[redacted]

CLASSIFICATION CHANGE

To [illegible]

By authority [illegible] CDS - 6P9

Changed [illegible] 12/4/74

Classified D[illegible] [illegible]tion, NASA

Scientific and Technical Information Facility

NASA AGENA D

MISSION CAPABILITIES

AND RESTRAINTS CATALOG

Volume 1

DOWN[illegible]ED AT 3 YEAR INTERVALS; DECL[illegible]ED AFTER 12 YEARS. [illegible]DIR 5200.10

This document contains information affecting [illegible]ational de[illegible] of the United States within the meaning of the Espionage Laws, Title 18, U[illegible]C., Sec[illegible] and 794. Its transmission or the revelation of its contents in any manner to [illegible]naut[illegible]ed person is prohibited by law.

INFORMATION CONTAINED ON TH[illegible]GE IS UNCLASSIFIED

[redacted]

E-3236-4

FOREWORD

The NASA Agena D Mission Capabilities and Restraints Catalog has been assembled by the LeRC-Agena Project to delineate the procedures followed and the Agena D equipment used in integrating a payload with an Agena D-booster combination. The catalog consists of two volumes. Volume I is classified (CONF.) and contains information on the mission capabilities of the Agena D. Volume II contains equipment, programming, and procedural information.

This Volume I document contains material generated by the Lockheed Missiles & Space Company to satisfy the requirements of the NASA-LeRC Statement of Work to contract NAS3-3805, Task 13. The -A revision is in accordance with Task 31 under the same contract.

E-3236-4

CONTENTS
(Volume I, Sections 1–4)

E-3236-4

E-3236-4

ILLUSTRATIONS

TABLES

E-3236-4

E-3236-4

E-3236-4

GENERAL INTRODUCTION

PURPOSE

The purpose of this document is to provide a single source of information regarding Agena D mission capabilities and restraints which affect spacecraft design. Utilized as a handbook during conceptual design and program planning, this catalog is intended to supplement the designer's knowledge of the Agena D and specify guidelines that enable him to design a spacecraft configuration which is:

- Compatible with the booster system
- Designed to realize maximum capabilities of the existing launch vehicle and associated equipment

SCOPE

This catalog presents significant spacecraft design parameters imposed by physical and functional characteristics of the Agena D (SS-01B)*/booster and associated AGE.

Volume I, Part I of the catalog presents the mission capabilities of the Agena D when used in conjunction with first-stage boosters. By using combinations of optional and program peculiar hardware developed and qualified for various NASA and Air Force programs, the Agena D can be applied as an intermediate stage booster or orbital vehicle, in the manner described for various missions in Part I. Performance characteristics of Agena D combinations in conjunction with Atlas and Thrust Augmented Thor (TAT) boosters are summarized to provide an envelope of capabilities for

*The SS-01B Agena vehicle is the AD-68-and-up configuration as defined by LMSC-1414870 "Detail Specification for the SS-01B and S-01B Vehicles (CONF)".

earth satellite and interplanetary missions. Although capable of a wide variety of orbital vehicle missions, the information presented for Agena is limited primarily to the boost missions. Orbital applications generally require special study.

Volume II of the catalog delineates major restraints imposed on the spacecraft by the launch vehicle and describes major Agena D and associated AGE equipment. Particular emphasis is given to mechanical, electrical and RF interfaces between the spacecraft and the Agena (including shroud). Mechanical, electrical, electronic, and other restraints are presented. In addition, environments imposed on the spacecraft during handling, testing, launch, and ascent are defined.

E-3236-4

Available hardware items described in Volume II, Parts IV & V, are those previously developed for second stage boost missions with separable spacecraft. Included are descriptions of major subsystems of the basic Agena D vehicle and the adaptations possible for meeting particular mission requirements. Of the optional and program peculiar hardware, only qualified* items are presented to give a comprehensive summary of configuration combinations.

Aerospace Ground Equipment descriptions and standard procedures for prelaunch and countdown activities are presented in Part IV to provide the spacecraft designer or planner with restraints imposed by launch complexes, launch base preparations and launch operations. To assist in program planning and to complete the presentation relative to interprogram coordination, a section is included in Part VII on Agena factory schedule sequences (including matchmate tests) and systems test operations, as well as major flight test support documentation. These activities usually require, at certain points in the schedule, hardware deliveries or documentary inputs relative to the spacecraft or mission requirements.

*The term "qualified" as used in this catalog implies that the item has qualified for flight or will be qualified in the near future.

E-3236-4

SECTION 1
REPRESENTATIVE MISSIONS

The purpose of this section is to describe, in terms of basic orbit mechanics, the part played by launch vehicles incorporating the Agena as an upper or intermediate stage in performing space missions. A launch vehicle mission (booster-Agena combination) will have been accomplished when its payload (a spacecraft) has been injected into an orbit whose characteristics have been specified in some reference frame before launch. The particular reference frame may or may not be fixed to the earth; the orbit may be circular, elliptical or hyperbolic, and may or may not intersect the earth's surface. To describe in general terms how each of these various missions are accomplished, it is convenient to divide the mission into two parts — the initial ascent phase, and the orbital phase. The term "initial ascent phase" will be applied to the first part of the trajectory, from liftoff until the instant the Agena achieves circular orbit.

1.1 INITIAL ASCENT PHASE

The initial ascent phase consists of two distinct segments—booster ascent and Agena ascent. The booster ascent segment begins at liftoff, and ends when the Agena separates from the spent first-stage. (The term "booster", as used in this report, refers to the first stage of the launch vehicle; the Agena will be called by its proper name, but is understood to be the second-stage booster.)

During booster ascent all thrust and direction control is provided by the booster vehicle. Objective is to lift the Agena and payload out of the atmosphere and to provide roughly half (value depends on the mission) of the total orbital velocity required by the mission. At the end of booster ascent, the launch vehicle will be in an earth-intersecting orbit known as the boost ellipse. The initial ascent phase is illustrated in Fig. 1-1 (minus 3-sigma degradations are assumed for the performance parameters of all stages in order to ensure predicted performance).

The Agena ascent segment begins with the physical separation of the Agena and its payload from the booster vehicle. As soon as possible after separation, the Agena engine fires. As the Agena's velocity increases, its instantaneous perigee moves radially outward from the boost ellipse. When perigee altitude reaches boost apogee altitude, the Agena has achieved a circular orbit, and the initial ascent phase can be considered as completed. Whether the Agena engine is shut down at this instant depends on the requirements of the mission, which are discussed below under "orbital phase."

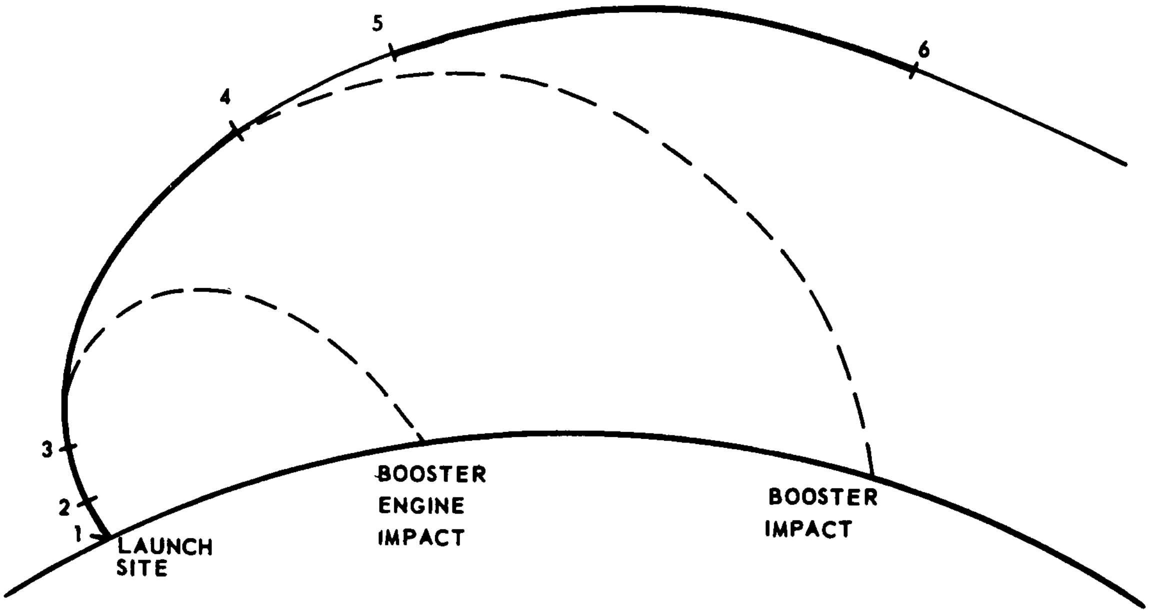
The design of the initial ascent phase is usually independent of the particular mission involved (launch azimuth, the exception, is discussed in 1.2.1). It is influenced most heavily by the choice of the booster vehicle; each booster has its own capabilities and restraints which confine the trajectory design of the booster ascent segment within narrow limits.

E-3236-4

1.2 ORBITAL PHASE

At the instant the Agena achieves circular orbit, the mission requirements begin to control the design of the flight. The initial ascent phase ends with the Agena's motor still burning. Some missions require a low-altitude, circular "parking orbit"; in such flights the motor will shut down as soon as this orbit is achieved. Others, however, require the motor to continue burning until the velocity required for a specified eccentric orbit is established. Because of the great variations in mission requirements, it is profitable to separate the discussion according to the type of final orbit involved: planar or non-planar earth orbital, sub-orbital, and lunar or interplanetary.

E-3236-4



POSITION	EVENT
1.	BOOSTER/AGENA LIFTOFF
2.	ROLL BOOSTER TO PROPER AZIMUTH AND START PITCHDOWN
3.	STAGE BOOSTER ENGINES (ATLAS) OR EMPTY SOLID BOTTLES (TAT)
4.	A. SHUTDOWN SUSTAINER ENGINE (ATLAS) OR MAIN ENGINE (TAT)
	B. SHUTDOWN VERNIERS
	C. SEPARATE SHROUD (OVER-THE-NOSE ONLY)
	D. SEPARATE AGENA AND PITCH DOWN TO ATTITUDE REQUIRED FOR AGENA FIRST BURN
5.	A. START AGENA ENGINE
	B. SEPARATE SHROUD (CLAMSHELL ONLY)
6.	SHUTDOWN AGENA ENGINE (AGENA IN ORBIT)

Figure 1-1 Initial Ascent Phase

E-3236-4

1.2.1 Earth Orbital Missions

1.2.1.1 Planar Missions. This paragraph presents the general techniques used in putting a spacecraft into a medium or high-altitude orbit about the earth. Foremost among these techniques is the Hohmann transfer, shown in a simple orbital mission in Fig. 1-2. For most Agena missions, Hohmann's method of changing the orbit is the most efficient, since it requires the minimum total impulse of the Agena. The dual-burn capability of the Agena makes this transfer method possible.

The Hohmann path is a 180-degree transfer ellipse between two coplanar orbits. If either the initial orbit or the final orbit, or both, are circular, the point of tangency may be anywhere on the circular orbit. The vehicle passes from one orbit to another at the point of cotangency, by changing its velocity from the value characteristic of one orbit to that of the other. The velocity change may be positive or negative, but it always lies along the velocity vector.

The true Hohmann transfer employs instantaneous changes in velocity, which cannot be achieved with actual hardware. However, a close approximation to this technique is possible since the burning times are a small fraction of the total flight time. This approximation diminishes the efficiency slightly and may change the timing of the burns by a few seconds. If first burn were to begin at boost apogee, the Agena, accelerating slowly due to its full load of propellants, might drop back into the atmosphere before achieving orbital velocity. Therefore, first ignition of the Agena must be programmed to take place while the vehicle is still coasting upwards toward boost apogee.

On lower altitude orbits where the payload requirement is substantially less than the launch vehicle's maximum (Agena dual burn) performance capability, a gain in reliability and injection accuracy is possible by firing all of the Agena's propellants in one long burn with burnout at the final orbit altitude (Fig. 1-3). The increase in reliability and in accuracy result from the

E-3236-4

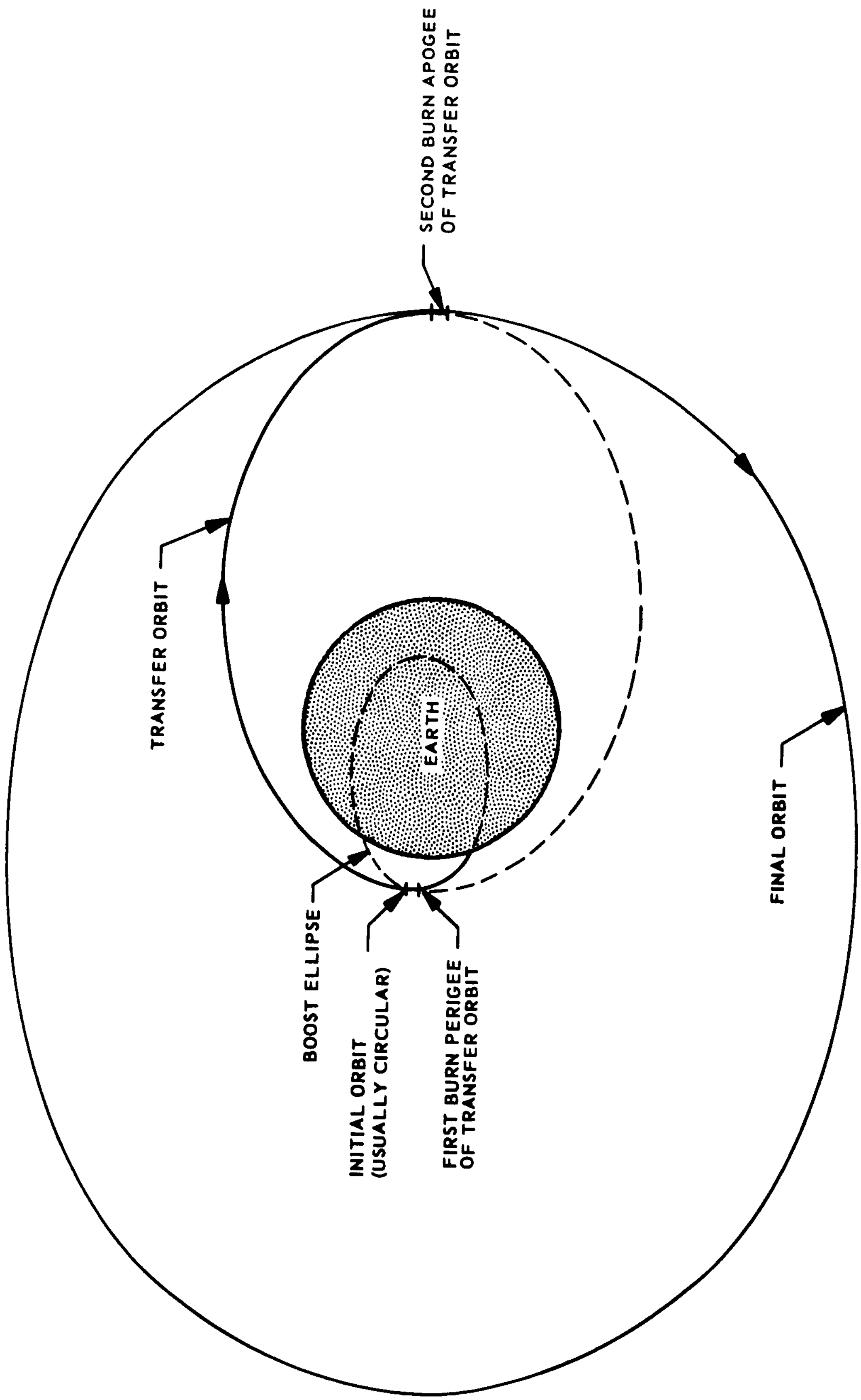


Figure 1-2 Typical Dual Burn Ascent Profile

E-3236-4

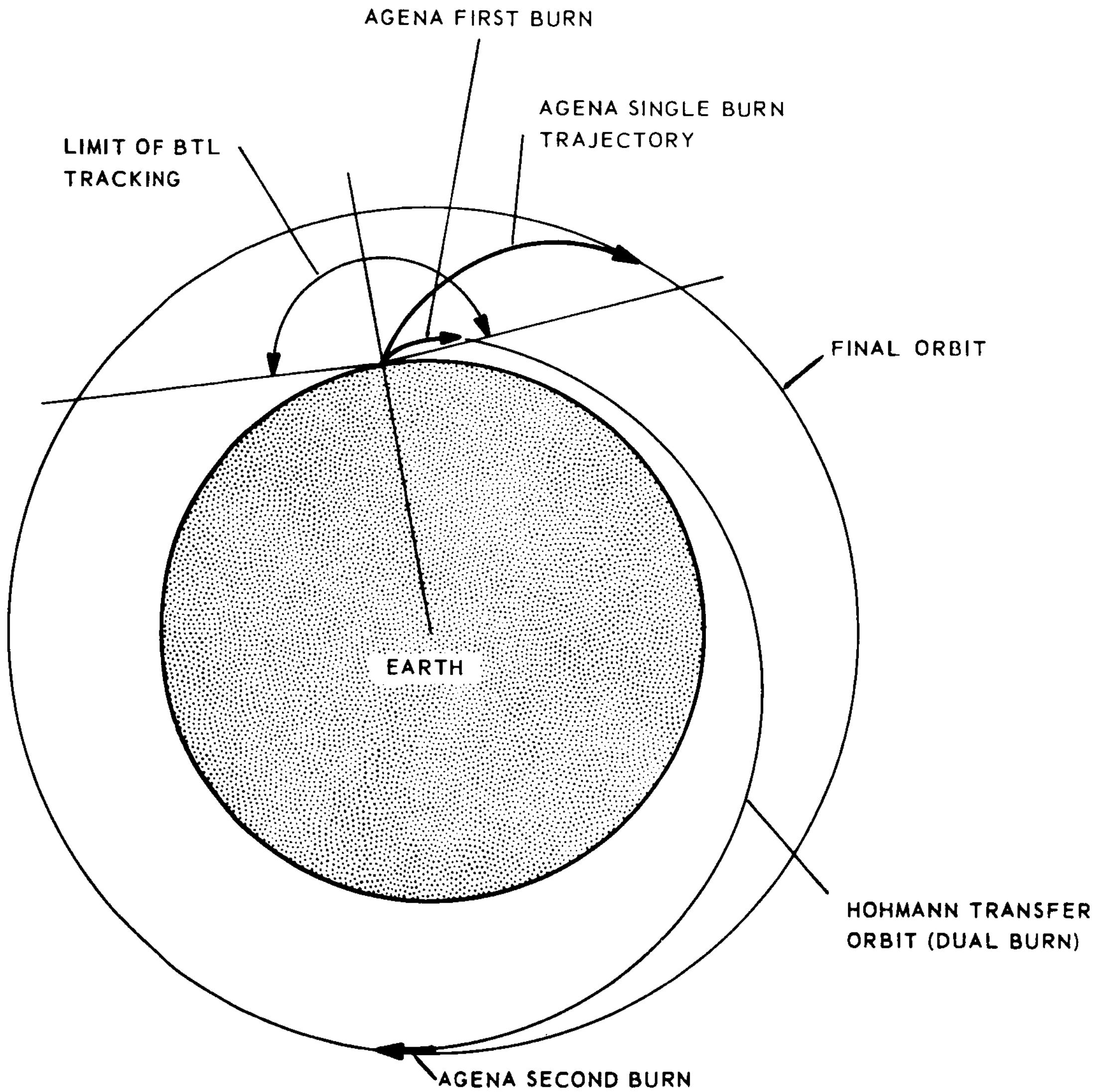


Figure 1-3 Comparison of Single-Burn and Dual-Burn Flights Into the Same Orbit

E-3236-4

elimination of the operations and consequent dispersions involved in second burn. A further accuracy improvement is obtained when it is possible (as it is on many Thor and TAT missions, not with Atlas) to use BTL closed-loop guidance (see Section 5) most or all of the way to final injection. This guidance system controls attitude and engine shutdown more accurately than the standard Agena "open-loop" system (see Section 16) which it augments; it cannot be used for second burn of a Hohmann transfer flight because it requires line-of-sight tracking and communications between the vehicle and the BTL ground station.

This discussion has treated the simple earth orbit in two dimensions (the pitch plane). The orientation of this plane with respect to the earth's axis (inclination) is ordinarily important, as well. Inclination is controlled by specifying the launch azimuth of the booster. Limitations in inclination due both to launch azimuth restrictions and to launch-site latitude are discussed below.

1.2.1.2 <u>Variations in Planar Missions</u>: Within the class of essentially two-dimensional orbital missions, many variations are possible. In addition to placing a spacecraft in an orbit of any of a variety of periods, shapes, and orientations, the Agena may be used to put multiple spacecraft either spaced around the same orbit, or into different orbits, on one flight. Two approaches can be used to achieve this objective: precision injection or random spacing.

<u>Precision Injection:</u> In a mission employing precision injection, Agena first burn injects the vehicle into a Hohmann-type transfer ellipse with apogee at the desired orbital altitude for the spacecraft. The second Agena burn is used to circularize the Agena orbit. Following this, the first spacecraft is ejected from the Agena at a small relative separation velocity.

The Agena is then yawed 180 degrees, after which the secondary propulsion system (SPS) applies what is then a retro-impulse. This puts the Agena and remaining spacecraft in an eccentric orbit with a period less than that of the circular orbit of the first spacecraft. When the first spacecraft has reached the desired position relative to apogee of the Agena orbit, the Agena is again yawed 180 degrees and the SPS used to accelerate the Agena into the original circular orbit of the first spacecraft. The second spacecraft is then ejected from the Agena.

In this manner, accurate relative placement of spacecraft is accomplished. Considerable precision is possible since the impulse provided by the SPS can be very accurately controlled by velocity meter cutoff. The number of spacecraft that can be launched from a single Agena is a function of the orbit altitude and the weight of the individual spacecraft.

E-3236-4

Random Spacing: In missions using the random spacing techniques, the Agena first burn again places the Agena in a transfer ellipse. In this case, the vehicle remains in the elliptical trajectory. The spacecraft are separated either at subsequent Agena apogees, or simultaneously. The spacecraft are equipped with solid motors which, after spacecraft ejection from the Agena, provide the additional impulse required for circularization. However, since the spacecraft solid motors have total impulse uncertainties which may be as high as five percent of the total available impulse, the spacecraft will enter somewhat different circular orbits. The trajectory paths will diverge with increase in the number of orbits. As a result, the angular spacing between the spacecraft will change, and periodic "bunching" will occur. Except for the lack of precision, this type of spacecraft injection offers material advantages. The staging brought about by equipping the individual spacecraft with motors improves mission payload capabilities.

Spacecraft with solid-propellant motors customarily require spinning to provide stabilization and directional control during rocket-engine firing. This can be accomplished by a spin table on the Agena or by a spin system on the spacecraft.

If the spacecraft have their own command system, they can all be separated at first apogee of the Agena transfer orbit. The first spacecraft engine is ignited immediately, and the remaining spacecraft remain in the transfer orbit until the proper spacings are achieved relative to the first spacecraft. Commands would be sent to each spacecraft in turn to ignite its engine and circularize its orbit. Alternatively, after separation of the first spacecraft, remaining spacecraft can remain attached to the Agena in the transfer orbit and be separated individually at succeeding apogees to provide the desired initial spacing.

1.2.1.3 Non-Planar Missions. The Agena flights described in the foregoing paragraphs take place essentially in a single, non-rotating plane (determined by launch azimuth) which contains the earth's center. Some missions, however, may require a change of plane to achieve the desired final orbit inclination.

One possible reason for a plane-changing maneuver is that the inclination of a planar mission's orbit cannot be smaller than the latitude of its launch site. The southernmost launch site in the continental United States is Cape Kennedy, whose latitude limits planar missions to inclinations greater than 28.5 degrees.

In order to rotate the plane of an orbit, it is necessary to add an out-of-plane component to the vehicle's velocity vector at the instant the vehicle reaches the axis of the desired rotation. The usual method is to yaw the Agena to the appropriate angle and fire its motor. The efficiency of this maneuver is greatest when it is performed at apogee, where the vehicle's velocity is lowest. A good example of a mission using this technique is a flight into a synchronous equatorial orbit (Fig. 1-4). The vehicle is launched from ETR at an azimuth of 90 degrees, which results in the lowest possible inclination before the plane change, and takes maximum advantage of the launch pad velocity due to earth rotation. The final circular orbit altitude is reached by a transfer orbit, modified in the same maneuver to rotate the orbit into the equatorial plane. The most efficient method is to combine the circularization with the plane change in the final burn; the combination requires only the vector sum rather than the algebraic sum of the two separate velocity changes. The axis of rotation must be in the equatorial plane so that final burn takes place at one of the nodes. This means that apogee of the transfer ellipse also occurs at this node, which places perigee at the other node. The interval between first burn-out and injection into perigee of the transfer orbit is connected by a circular parking orbit. Figure 1-4 shows the shortest possible flight, which results in the satellite taking station over the Pacific Ocean. To achieve a station at some other longitude, it is only necessary to lengthen the flight while the earth rotates, which postpones either second or third burn to a later nodal passage.

E-3236-4

A considerable increase in synchronous equatorial payload is possible if the plane change and circularization are accomplished by a solid rocket in the spacecraft, eliminating the acceleration of the Agena into the final orbit. After second burn of such a mission, the Agena yaws to orient the spacecraft thrust line in the inertial direction required for third burn. The spacecraft is then spun about its thrust axis and released. When it reaches transfer apogee, its timer fires its motor, injecting it into the final orbit.

1.2.2 Suborbital Missions

The Agena may be used for suborbital flights, such as hyperbolic* reentry research. In a typical mission, Agena first burn is shorter than in an orbital flight, ending with the vehicle on a ballistic trajectory with an apogee altitude of several hundred nautical miles. Between apogee and reentry the Agena pitches down past the horizontal and fires its engine again, raising its incoming velocity. After separation, the payload, which may be spin-stabilized, fires its own motor to achieve hyperbolic velocity.

1.2.3 Lunar and Interplanetary Missions

Lunar and interplanetary missions present in common a complex problem in guidance and trajectory design – to hit a moving target (e.g., the moon or a planet) from a rotating launch platform (the earth). The motions of the bodies involved are known, so that, given a launch time and an arrival time, one could compute the positions of the launch site and the target, and

*Tests at velocities exceeding those of escape

E-3236-4

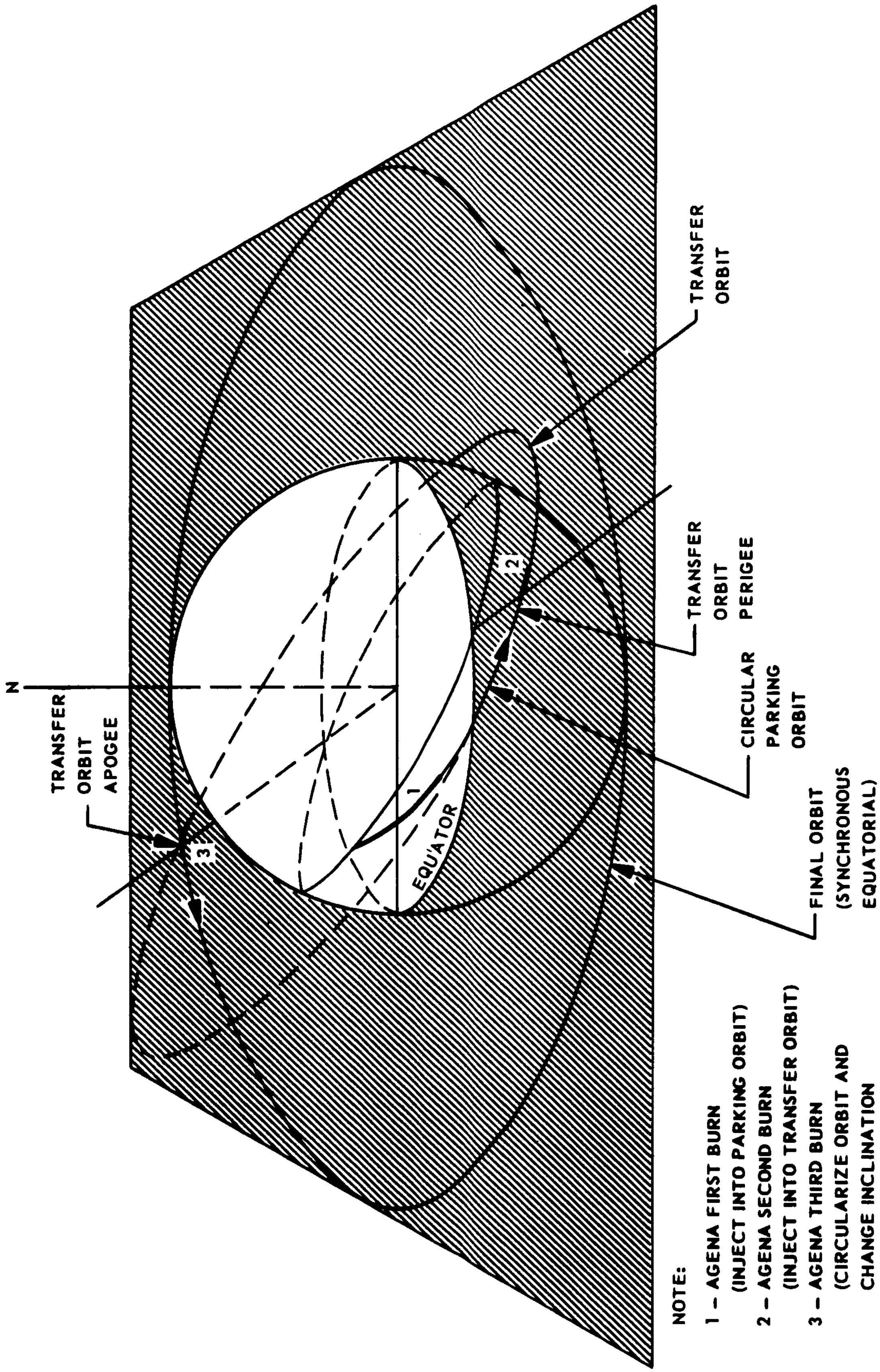


Figure 1-4 Synchronous Equatorial Orbit Mission

design an intercept trajectory to connect these points. In fact, however, the complex countdown procedure, with its unpredictable delays, makes it necessary to allow a finite period of time during which a launch may be attempted, and to adjust the planned intercept trajectory continuously during this period so that interception of the target will be possible whenever liftoff actually occurs. The discussion that follows will describe briefly the first approximation to the solution employed in the Ranger, Mariner-R, and Mariner-Mars missions, which use the Atlas-Agena to boost spacecraft towards the moon, Venus, and Mars, respectively.

E-3236-4

Ranger travels to the moon in a highly eccentric earth orbit (Figure 1-5) which is perturbed by the gravitational attraction of the moon. Perigee of this earth orbit defines an injection point in inertial space. The launch vehicle's function is to carry the spacecraft to the injection point, and there to accelerate it to the perigee velocity of the earth-moon transfer orbit. The initial ascent phase of the mission puts the Agena into a circular parking orbit which passes through the injection point. As the earth rotates, the distance from the launch site to the injection point diminishes, requiring a progressively shorter coasting time in the circular parking orbit as liftoff occurs later in the launch window. The necessary adjustment in the sequence is accomplished simply by computing as a function of liftoff time the time interval between first burnout, when the circular parking orbit is achieved, and second burn, which injects the Agena into the transfer orbit. It is also necessary for launch azimuth to increase with liftoff time since, as the earth rotates, the latitude of the launch site remains constant while the longitude difference between it and the injection point grows smaller. A modification of the Atlas guidance system permits launch azimuth, which controls inclination, to vary with liftoff time. This also changes the inclination of the earth-moon transfer orbit, so that it rotates about its major axis with increasing liftoff time. In general, therefore, the moon does not lie in the plane of the orbit. This condition is permissible, within limits, because the distance of the moon from the major axis is comparatively small (due to the orbit's high eccentricity) and most of the resulting miss distance can be eliminated by small corrections in trajectory design. Another small

E-3236-4

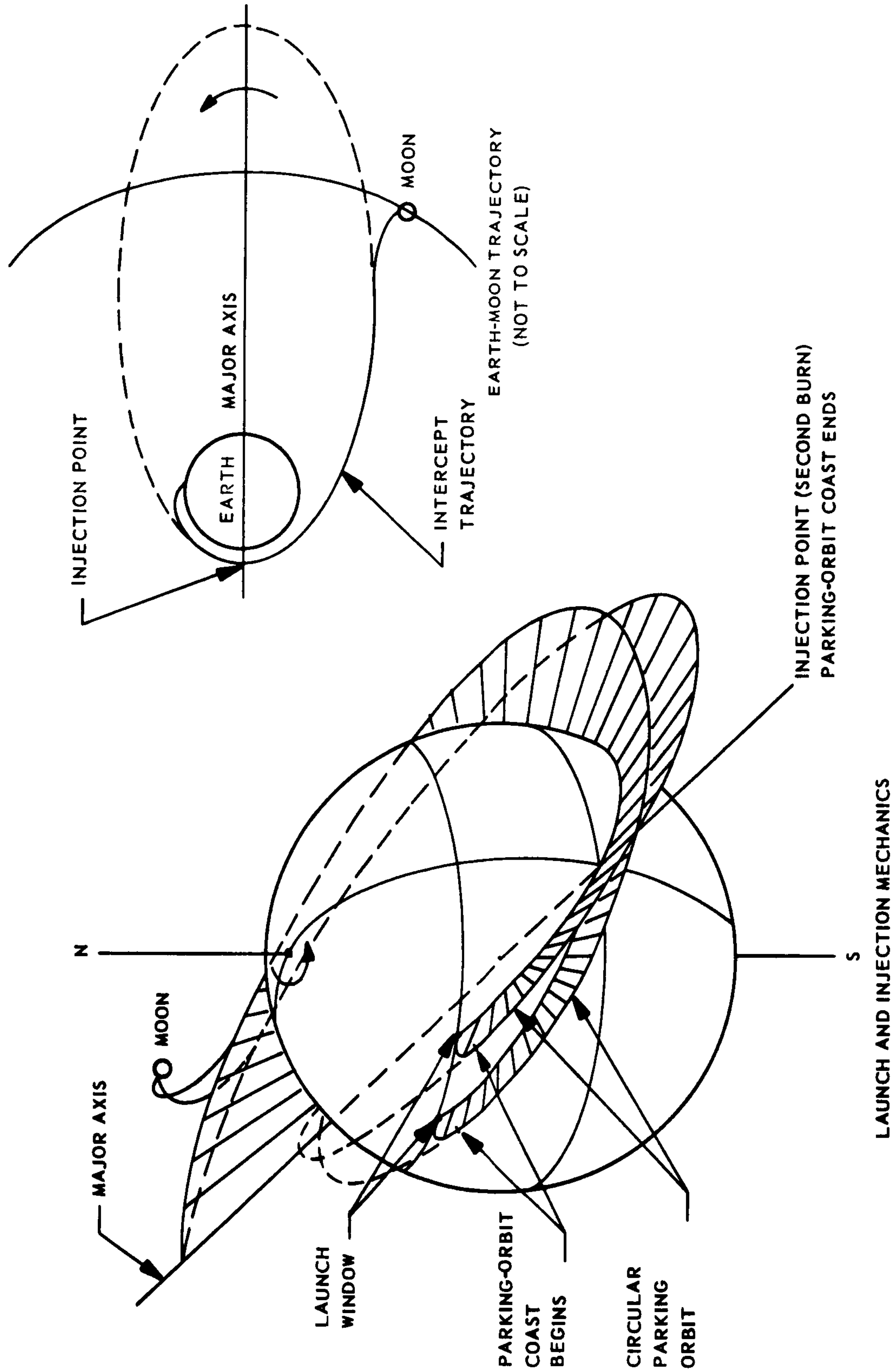


Figure 1-5 Lunar Mission

correction is necessary to account for the moon's motion; this causes the injection point to move slowly, rather than remaining inertially fixed.

E-3236-4

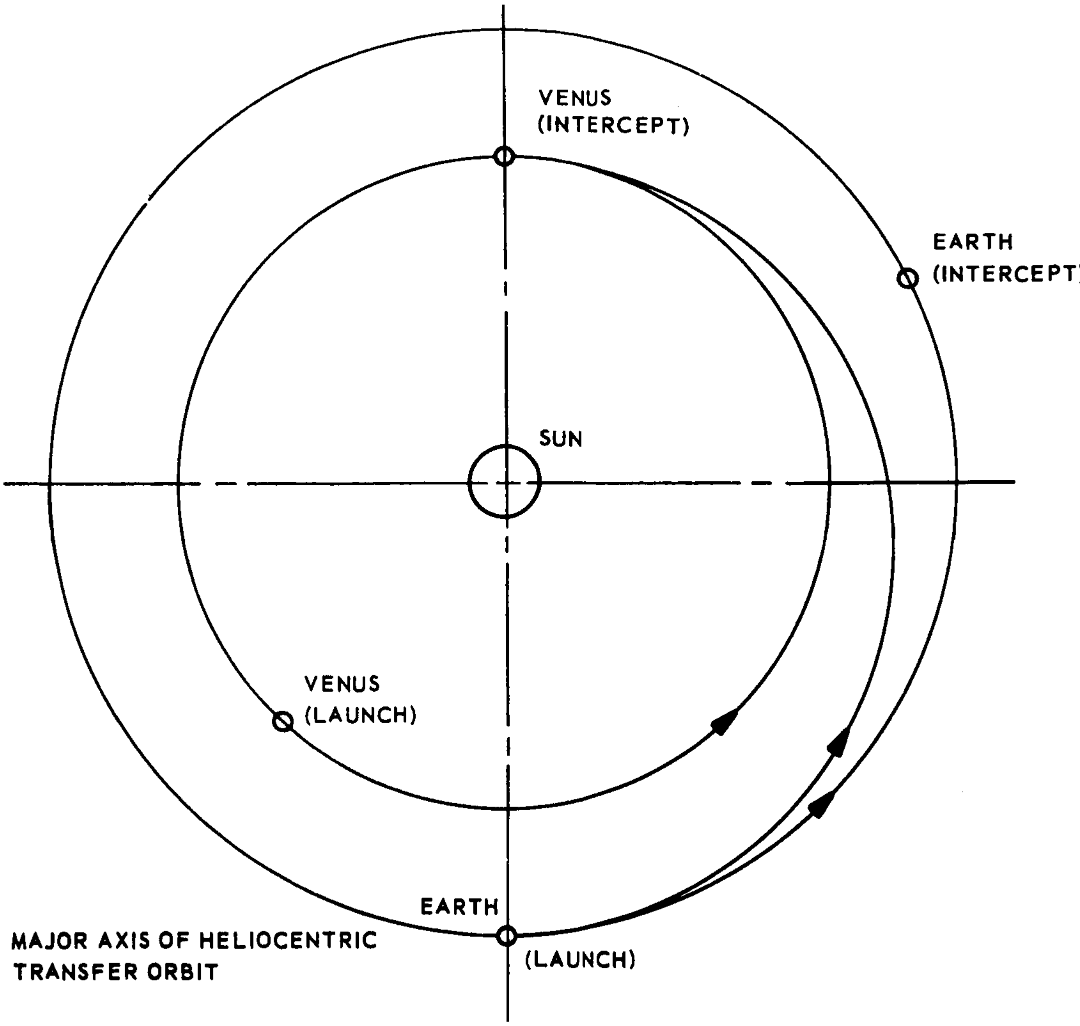
The two variables, launch azimuth and parking orbit coast time, are computed as functions of launch time and published in the form of firing tables. Only certain launch azimuths (90 to 114 degrees, approximately) are normally permitted at the Eastern Test Range, because of range safety constraints; these correspond to certain liftoff times which define the mission's daily launch window.

In an interplanetary mission (Figure 1-6), the injection point is approximately on the major axis of the heliocentric transfer orbit. At injection, the vehicle achieves a hyperbolic (escape) orbit with respect to earth. For a journey to an inferior planet, the spacecraft must be injected near apogee of the heliocentric transfer orbit so that injection velocity is in the opposite direction to the earth's orbital velocity. The trajectory design uses the same two variables (launch azimuth and parking orbit coast time) used in the lunar mission. The changing inclination of the parking orbit (resulting from the variable launch azimuth) gives rise to a varying angle between the geocentric injection velocity vector and the earth's orbital velocity vector. The resulting change in the heliocentric orbit's inclination is much smaller, however, because the earth's velocity is more than three times larger. Since the target planet is encountered approximately at the apsis opposite injection, there is little danger of missing it due to this inclination change; the primary effect is a small increase in required geocentric injection velocity.

1.3 LAUNCH WINDOWS

The preceding discussion touched on the launch windows defined by the combination of variable launch azimuths required for lunar and interplanetary missions with launch azimuth restrictions imposed by range safety requirements. A launch window of a more general form exists whenever a mission requires its final orbit to have a specific orientation with respect to some

E-3236-4



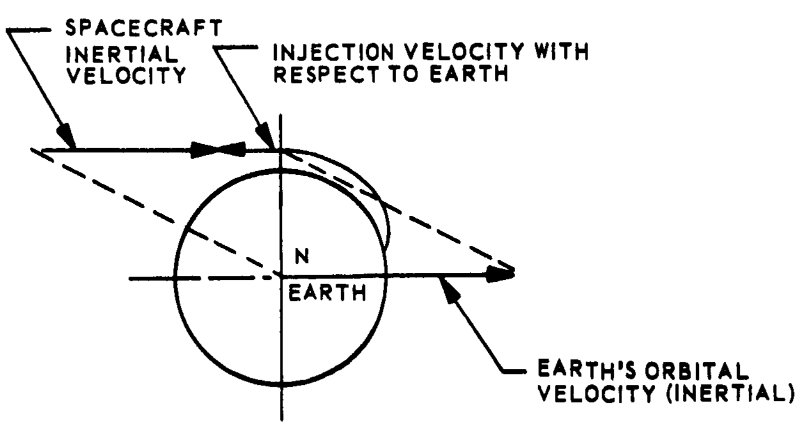


Figure 1-6 Interplanetary Mission (Venus Flyby)

reference (e.g., the sun, the ecliptic plane, etc.) which does not rotate with the earth. Except for the lunar and interplanetary missions, the point of injection into the final orbit is fixed over the rotating earth, and defines an orbit fixed to the earth's position at injection or liftoff. The orbit may be thought of as a hypothetical orbit, rotating with the earth until liftoff; and at liftoff, the actual orbit is determined. There is, therefore, one instant each day at which a launch will result in the desired orbit orientation with respect to the non-rotating reference. The allowable errors in this orientation give rise to tolerances in the liftoff time, which in turn define the launch window.

A secondary restriction on the launch window arises from the inability of the Agena's attitude control system to function properly when the sun passes into the field of view of its optical horizon sensors. Whether this will happen on a given flight depends on the orientation of the vehicle with respect to the sun, or in other words, on the positions of the vehicle and the sun with respect to the earth. Since the former is a function of the trajectory flown, and the latter is a function of liftoff time, it is possible to discover the liftoff times which would result in horizon-sensor sun interference and eliminate them from the launch window.

E-3236-4

E-3236-4

Section 2
LAUNCH VEHICLE PAYLOAD WEIGHT CAPABILITIES

2.1 GENERAL

Capability data for two booster vehicles in combination with three typical Agena configurations are presented in this section. These launch vehicle configurations are representative of the missions to which an Agena second-stage is applied. The data are shown for ETR and WTR launch sites considering launch azimuths of 90 and 114 deg at ETR while the WTR data presents inclined orbit capability for inclinations of 80 deg prograde, 90 deg (polar), and 80 deg retrograde. Payload weight* is shown as a function of both circular orbit altitude and characteristic velocity for the boosters and Agena weights considered.

Discussed in this section will be the propellant margins required in the booster and/or Agena stages to guarantee engine shutdown before propellant depletion under the influence of 3-sigma vehicle tolerances. Payload capability for the Standard Atlas/Agend D and TAT/Agena D are presented in 2.4 and 2.5, respectively. The Standard Atlas/Agena D payload capability is for the Lunar Orbiter Type Equipment (par. 2.4.1), EGO Type Equipment (par. 2.4.2), and OAO Type Equipment (par. 2.4.3). Payload capability for the TAT/Agena D is for the POGO Type Equipment (par. 2.5.1).

Typical Earth orbit and extra-terrestrial probe launch sequence of events for the Atlas/Agena D are given in Table 2-1. Sequence of events for typical Earth orbit TAT/Agena D launches with Agena dual burn is listed in Table 2.2. These sequences will change with mission and additional events may be added, dependent upon the payload requirements.

---

*See par. 2.2-(e) for definition.

E-3236-4

Table 2-1

TYPICAL ATLAS/AGENA SEQUENCE OF EVENTS

EARTH ORBIT MISSION

Event	Time from Launch (Sec)
1. Liftoff	0.0
2. Start Booster Preprogrammed Roll Maneuver	2.0
3. Stop Booster Preprogrammed Roll Maneuver	15.0
4. Booster Cutoff*	132.0
5. Booster Cutoff Backup (Acceleration Level Switch Set at 6 ± 1 G)	
6. Start Sustainer Pitch Program	142.0
7. Sustainer Engine Cutoff*	281.6
8. Start Agena Primary Timer*	295.0
9. Vernier Engine Cutoff*	301.6
10. Eject Over-The-Nose Shroud*	302.6
11. Fire Atlas/Agena Separation Pyrotechnics*	307.6
12. Connect H/S Roll Output to Roll Gyro; Activate Pneumatic Servos (Agena Leaves Booster Adapter)	310.1
13. Start Pitch Down	329.0
14. Stop Pitch Down, Transfer to First Geocentric Pitch Rate; Connect H/S Pitch	
15. Agena First Burn Ignition; Enable VM	357.0
16. Agena First Burn Cutoff	579.5
17. Agena Back Up Shutdown (Timer); Vent Propellent Lines	589.0
18. Transfer to Second Geocentric Pitch Rate. F/C and Pneumatic to Orbit Mode; Begin Gyrocompassing; Set H/S Bias Angle to Zero Deg	600.0
19. Recover from Gyrocompassing; F/C and Pneumatic to Ascent Mode; Transfer to Second Burn Velocity-to-be-Gained Number	3831.0

*Command by Radio Signal from a Ground Computer

E-3236-4

Table 2-1 (Cont.)

EARTH ORBIT MISSION (Cont.)

	Event	Time from Launch (Sec)
20.	Close Propellant Line Vents; Enable VM	3889.0
21.	Agena Second Burn Ignition	3891.0
22.	Agena Second Burn Cutoff	3910.0
23.	Eject Payload	4010.0
24.	Start 90-Deg Yaw Maneuver (3 Deg/Sec)	4013.0
25.	Stop 90-Deg Yaw Maneuver Recover to Nose Right Gyrocompassing in Orbit Mode	4043.0

EXTRA-TERRESTRIAL PROBE LAUNCH MISSION

In the case of an extra-terrestrial probe launch, the time of second burn ignition will vary during the launch opportunity. This necessitates stopping the primary timer after first burn shutdown and restarting it after a coast whose duration is also a variable function of time into the launch window. Control of the primary timer is a sole function of the restart timer. The above sequence is altered by the addition and modification of the following events.

	Event	Time from Launch (Sec)
6a.	Start Agena Restart Timer	243.0
16a.	Agena First Burn Cutoff	507.0
18a.	Stop Agena Primary Timer; (Close the Helium Pressurization Valve; stops active pressurization of Propellant Tanks. This pressurization requires a nominal 300 sec from start of ignition. It is common to all varieties of Agena Missions, but in this case defines the maximum time interval the Primary Timer must run out after ignition before shutting down.	657.0
18b.	Restart Agena Primary Timer; Recover from Gyrocompassing to Ascent Mode (If the Coast is less than 600 sec, Gyrocompassing is not done. Coast time can vary from 300 to 2000 secs.)	1700.0
21.	Agena Second Burn Ignition	1760.0
22.	Agena Second Burn Cutoff	1850.0

Table 2-1 (Cont.)

EXTRA-TERRESTRIAL PROBE LAUNCH MISSION (Cont.)

	Event	Time from Launch (Sec)
23.	Ejection Payload	2000.0
24.	Yaw 180 Deg	2003.0
25.	Stop Yaw, Transfer to Geocentric Rate of Opposite Polarity (Now Coasting Tail First)	2063.0
26.	Fire Retrograde Rocket; (This is done to perturb the Agena Trajectory sufficiently to miss the target celestial body and to preclude close approach to the Payload in the event it performs midcourse maneuvers.)	2600.0

E-3236-4

E-3236-4

Table 2-2

TYPICAL TAT/AGENA DUAL BURN SEQUENCE OF EVENTS

EARTH ORBIT MISSION

In this type of mission the Command Guidance Receiver is carried in the Agena. This System first steers the Booster, signals MECO and separation, and at separation its outputs are transferred to the Agena. During engine burn the Agena is command guided in Pitch and Yaw and the engine cutoff by a discrete.

	Event	Time from Launch (Sec)
1.	Liftoff	0.0
2.	Start Booster Pre-programmed Roll Rate	2.0
3.	Start Booster Pitch Program; Yaw also if required	4.0
4.	Change Booster Preset Pitch Rate, Stop Yaw and Roll	10.0
5.	Auxiliary Solid Propellant Booster Burnout	41.0
6.	Jettison Auxiliary Booster Cases	65.0
7.	Main Engine Cutoff, Start Agena Timer*	148.0
8.	Main Engine Cutoff, Start Agena Timer (Backup by Depletion Switch)	—
9.	Vernier Engine Cutoff, Uncage Agena Gyros, Jettison H/S Fairings	157.0
10.	Fire Thor/Agena Separation Pyrotechnics*	160.0
11.	Transfer Command Guidance to Agena (Agena First Motion Out of Booster Adapter)	160.2
12.	Activate Agena Pneumatic Attitude Control Servos (Agena Leaves Adapter); Connect H/S Roll Output to Roll Gyro	162.0
13.	Start High Rate Pitchover, Approximately 1.0 deg/sec, Enable Pitch and Yaw Steering Inputs	169.0
14.	Stop High Rate Pitchover, Transfer to 1st Geocentric Pitch Rate	172.0
15.	Enable VM, Agena First Ignition	177.0
16.	Jettison Clam-Shell Shroud	187.0

*Command by Radio Signal from a Ground Computer

Table 2.2 (Cont.)

EARTH ORBIT MISSION (Cont.)

	Event	Time from Launch (Sec)
17.	Enable VM Counter; Stop Command* Guidance Steering (Acceleration pulses now enter the counter and subtract from a stored binary number representing the remaining first burn velocity to be gained; the Agena is now guided in pitch and yaw by its Gyros)	359.0
18.	First Burn Cutoff by V/M	389.0
19.	Backup Cutoff (Agena Timer); Vent Propellant Lines	399.0
20.	Connect H/S Pitch Output to Pitch Gyro; Start Gyro-compassing; Transfer to Second Geocentric Pitch Rate; Transfer F/C and Pneumatics to Orbit Mode	415.0
21.	Recover from Gyrocompassing to Ascent Mode, Transfer Second Burn Velocity-to-be-Gained Number into Counting Register of V/M; Transfer to Third Geocentric Pitch Rate	4910.0
22.	Open Propellant Isolation Valve (Closes Propellant Lines Vents) Enable V/M	4942.0
23.	Agena Second Burn Ignition	4944.0
24.	Agena Second Burn Cutoff	4956.0
25.	Eject Payload	5056.0
26.	Start +90 Deg Yaw Maneuver at 3 Deg/Sec	5059.0
27.	Stop +90 Deg Yaw Maneuver; Transfer Geocentric Rate to Roll Channel; Transfer F/C and Pneumatic to Orbit Mode.	5089.0

*Command by Radio Signal from a Ground Computer

E-3236-4

E-3236-4

2.2 UNDERLYING ASSUMPTIONS

Generalized payload (orbit) altitude curves are meaningful only in light of arbitrarily fixed variables. In order to perform the computations necessary to derive the payload capability shown, the following assumptions were made:

(a) Booster models used were the Standard Atlas (SLV-3) and the TAT (LV-2A). Typical weight summaries for these vehicles are tabulated in Tables 2-3 and 2-8.

(b) The Agena models and nose shroud weights are presented in par. 2.4 and 2.5. Shrouds are dropped just before booster separation (over-the-nose type) or ten (10) seconds after Agena first burn ignition (Standard Clamshell Type). The weight breakdown and weight sequences for the Agena are shown in the following tables:

2-5 Typical Lunar Orbiter Type Agena D Weight Summary (Atlas Booster)

2-6 Typical EOGO Type Agena D Weight Summary (Atlas Booster with Standard Agena Clamshell Shroud)

2-7 Typical OAO Type Agena D Weight Summary (Atlas Booster)

2-9 Typical POGO Type Agena D Weight Summary (TAT Booster with Standard Agena Clamshell Shroud and BTL in Agena)

The equipments listed in these tables are considered to be essentially standard modifications or items used in configuring the Agena for NASA missions of the type exemplified. These equipments will be used without modification or substitution of other items to the maximum extent feasible for each LeRC conducted Agena Mission.

(c) All orbit transfers were accomplished by Hohmann transfer, at a perigee of 100 nm for the Atlas and 85 nm for the TAT.

(d) Payload capabilities are minus three-sigma values, obtained by reserving sufficient propellant in the booster (none in TAT due to soft shutdown) and Agena to permit the achievement of the desired energy by overcoming the three-sigma deviations. A constant Atlas booster propellant margin of 721 pounds was used while the Agena propellant margin was variable as derived in par. 2.3.

(e) For all the missions presented here, the payload weight includes payload support; e.g., for example, any additional battery, control gas, or timer weights, etc. (not listed in the weight tables used herein) and spacecraft adapter weight plus attendant equipment must be deducted from the payload read from the curves to obtain the weight to be assigned to the spacecraft.

(f) Qualifying input assumptions restricting the use of the performance curves are given on each figure.

E-3236-4

2.3 PROPELLANT MARGINS

The propellant margins for a specific mission are determined by performing a booster and upper stage error analysis about a closed-loop guided nominal trajectory. Error sources for each Booster and Agena vehicle component; for the radio guidance system, and for the trajectory environment are individually introduced into this closed-loop simulation and the effect on propellant margin obtained. The results are then statistically combined; usually root-sum-squared unless non-linearities predominate, to determine the propellant margin for both booster and upper stage vehicles. The error sources associated with the Atlas-Agena and TAT Agena combinations exhibit essentially linear characteristics* and, therefore, adequate composite propellant margins may be determined by root-sum-squaring the individual contributions.

Historically, a 38-lb contingency is withheld from the payload quotes up until the time when booster tag values are used to determine payload capability. At this time the 38-lb contingency is dropped; propellant margins evaluated for tag error sources, and adjustment made to assure a 3-sigma margin at a 90-percent confidence level. All performance data given herein utilize batch propellant margins with the 38-lb contingency subtracted from the payload capability.

---

*This fact is shown in "Final Report Task No. 10," LMSC-A603407.

E-3236-4

2.3.1 Atlas/Agena

For this study, as well as other general performance studies, a fixed Atlas booster margin was chosen and utilized for all missions. As shown in the weight statement (Table 2-3), the Atlas Booster margin was set at 721 lbs which represents a typical value and varies only slightly over the entire range of missions. For the Agena, the margin requirement is highly dependent on the mission, varying by a factor of two between the characteristic velocities of 26,000 and 36,000 ft/sec. Therefore, for the Agena margin, a set of partials is used to obtain propellant margin requirements in lieu of a closed-loop error analysis for the range of missions. The significant Agena dispersions used to determine propellant margins are propellant utilization, inert weight variations, propellant tanking, and specific impulse. These requirements are then root-sum-squared to obtain the Agena margins. This is illustrated as follows:

$$\begin{pmatrix}\text{Agena}\\ \text{Propellant}\\ \text{Margin}\end{pmatrix}_{\substack{\text{Atlas}\\ \text{Boosted}}} = \sqrt{\left(\frac{\partial W_p}{\partial PU}\Delta PU\right)^2 + \left(\frac{\partial W_P}{\partial W_I}\Delta W_I\right)^2 + \left(\frac{\partial W_p}{\partial P}\Delta P\right)^2 + \left(\frac{\partial W_p}{\partial I_{sp}}\Delta I_{sp}\right)^2}$$

where:

W_p = Propellant weight
PU = Propellant utilization
W_I = Inert weight
P = Propellant loaded
I_{sp} = Propellant specific impulse
Δ = The 3-sigma deviation on the quantity following

E-3236-4

2.3.2 TAT/Agena

For the TAT boosted Agena, modified soft-cutoff* in the booster was utilized and the Agena margin therefore was computed to accomodate both Agena and TAT dispersions. The procedure used involves the determination of Agena propellant requirements to offset these 3-sigma booster dispersions. These additional dispersions are then root-sum-squared with the Agena deviations to obtain the total margin requirement. This is illustrated as follows:

$$\begin{pmatrix}\text{Agena}\\ \text{Propellant}\\ \text{Margin}\end{pmatrix}_{\substack{\text{TAT}\\ \text{Boosted}}} = \sqrt{\Sigma(\partial)^2 + \sum_{1}^{N}\left(\frac{\partial W_p}{\partial e_n}\Delta e_n\right)^2}$$

where:

$\Sigma(\partial)^2$ = The sum-square of Agena propellant requirements as defined above in the Atlas/Agena discussion. (par. 2.3.1)

$\sum_{1}^{N}\left(\frac{\partial W_p}{\partial e_n}\Delta e_n\right)^2$ = The sum-square of the Agena propellant requirements to offset booster dispersions.

2.4 PAYLOAD CAPABILITY—STANDARD ATLAS/AGENA D

Payload capability curves for a Standard Atlas (SLV-3)/Agena D have been generated from a series of dual burn trajectory runs. These runs (together with hand computations) are used to determine the effect of inclined orbits and eccentric orbits. Basic computer runs were made for ETR launches at a 90-deg azimuth and for polar orbits launched from the WTR with injection at 100 nm. The weight summary of the Atlas is presented in Table 2-3.

---

*No margin allowance in the booster (TAT); i.e., there is an equal probability that the booster will be cut off by either propellant depletion or by command guidance.

E-3236-4

Table 2-3

TYPICAL ATLAS (SLV-3) WEIGHT SUMMARY

SUSTAINER DRY WEIGHT	6,010	
Trapped Propellants	272	
LOX Depletion Shutdown Reserves	200	
Fuel P. U. Bias	115	
Helium and Nitrogen	93	
LOX Boiloff in Tanks	266	
Performance Reserves Propellants	721	
SUSTAINER JETTISON WEIGHT		7,677
BOOSTER DRY WEIGHT	6,290	
Trapped Propellants	1,058	
Helium and Nitrogen	48	
BOOSTER JETTISON WEIGHT		7,396
BOOSTER AND SUSTAINER IMPULSE PROPELLANTS		246,549
Vernier Engine Propellants		210
Lube Oil Loaded		219
LOX Overboard		40
TOTAL SLV-3 WEIGHT AT LIFTOFF (LESS AGENA AND SPACECRAFT		262,091
Ground Run and Engine Start Consumption		2,681
TOTAL SLV-3 WEIGHT (LOADED CONDITION)		264,772

*This weight summary was used for both ETR and WTR launches.

Total drop weights (including shroud weight) and Agena inert weights at burnout were taken to be those associated with the Lunar Orbiter, the EOGO, and the OAO missions, see Tables 2-5, 2-6, and 2-7, respectively. The following Table 2-4 summarizes the data used:

E-3236-4

Table 2-4

DROP WEIGHT DATA

Mission	Nose Shroud Weight (lbs)	Total Drop Weight At Separation Including Shroud (lbs)	Agena Inert Weight (lbs)
Lunar Orbiter	374	789	1419
EOGO	649	1062	1412
OAO	1873	4039	1499

The launch azimuth restrictions at the WTR require "dog-leg maneuvers"* to obtain orbit inclinations less than 82 deg. The exact losses for dog-legging to 80-deg prograde orbits are a complex function of the mission, the allowable launch azimuth, the time of dog-leg, and the vehicle turning rate used for the dog-leg. These variables in turn are closely related to constraints on the system such as maximum allowable angle-of-attack (and/or sideslip), separation angle-of-attack, the product of angle-of-attack and dynamic pressure (αq), and the radio guidance "look angles." Because of this complexity, the solution for 80-deg prograde orbits has not been attempted. Based on past studies, performance penalties for a two-deg dog-leg were found to be insignificant. Therefore, the Atlas/Agena capabilities were generated without considering dog-leg maneuvers.

The payload capability plots are presented as functions of characteristic velocity, circular orbit altitude, and eccentric orbit apogee capability for ETR and WTR launches for the three Agena D configurations.

---

*Out of plane maneuvers

Characteristic velocity is defined as the sum of the parking (or transfer) orbit velocity and all subsequent velocity changes (with respect to the local horizontal) made to achieve the final orbit or mission desired. Gravity loses during these subsequent velocity changes are neglected. It is readily seen that any sequence of Hohmann transfers may be reduced to an equivalent characteristic velocity. Typically, the characteristic velocity curves are the base reference in a performance analysis, and orbit capability determinations are made from interpretations of the characteristic velocity curves.

To facilitate computation of payload for elliptic orbits with perigee altitudes higher than 100 nm, Fig. 2-1 provides elliptic orbit conversion curves for perigee altitudes of 200, 300, and 400 nm in terms of characteristic velocity for Agena dual burn. In addition, vis viva energies (C_3) for the aforementioned perigee altitudes are shown as a function of characteristic velocity. Curves consider injection of the Agena at 100-nm perigee (first burn). A typical payload capability curve resulting from this conversion is shown in Fig. 2-11 which gives the Atlas/Agena D EOGO configuration in terms of apogee altitude for 200, 300, and 400 nm.

Extreme care has been exercised to optimize specific trajectory runs for the capability plots shown here, but the plotting and joining of specific points with a smooth curve will result in some errors in the payload values. The plotting errors should be less than one-half of the scale least count. Therefore, using this criteria the associated performance tolerances should be less than:

Payload-Characteristic Velocity Plots	25 lbs
Payload-Altitude Plots	50 lbs

[redacted]

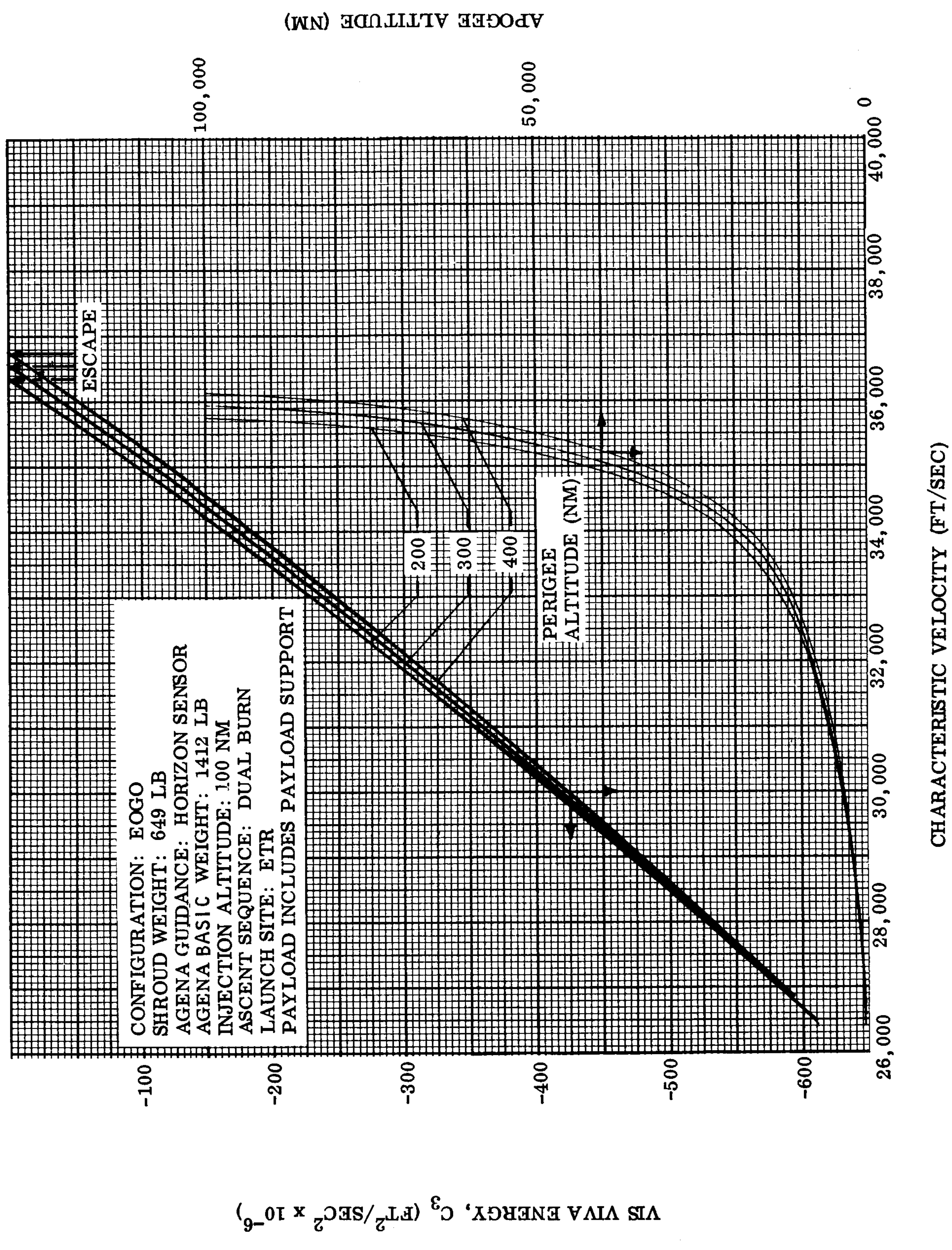


Fig. 2-1 Atlas/Agena Elliptical Orbit Conversion Curves

E-3236-4

[redacted]

E-3236-4

2.4.1 Lunar Orbiter Type Equipment

The weight breakdown and weight sequence for the Agena used with the Atlas booster vehicle is shown in Table 2-5, Typical Lunar Orbiter Type Agena D Weight Summary (Atlas Booster).

The performance data are presented for the vehicle configuration as follows for the indicated launch site:

Figure	Launch Site	Description
2-2	ETR	Payload vs. Characteristic Velocity, Lunar Orbiter Type Equipment
2-3	ETR	Payload vs. Circular Orbit Altitude, Lunar Orbiter Type Equipment
2-4	ETR	Payload vs. Elliptical Orbit Apogee, Lunar Orbiter Type Equipment
2-5	WTR	Payload vs. Characteristic Velocity, Lunar Orbiter Type Equipment
2-6	WTR	Payload vs. Circular Orbit Altitude, Lunar Orbiter Type Equipment
2-7	WTR	Payload vs. Elliptical Orbit Apogee, Lunar Orbiter Type Equipment

Table 2-5

TYPICAL LUNAR ORBITER TYPE AGENA D WEIGHT SUMMARY

(Atlas Booster)

AGENA D COMMITTED WEIGHT EMPTY			1,496
REMOVALS			-33
Self Destruct Items		-20	
Shorting Connectors		-1	
Pressurized RF Switch		-2	
Coax Cables		-2	
Sequence Timer		-8	
OPTIONALS			188
Command Destruct		35	
Booster Adapter Extension Kit		90	
Booster Adapter Extension Ring Kit		10	
Battery Kit Type IV (2)		32	
Flight Control Patch Panel Kit		1	
TM Transmitter Adapter Kit		4	
Sequence Timer (Wired)		8	
Restart Timer Kit		8	
PECULIARS			485
Transducers and Brackets		7	
Retro-Rockets		18	
Wiring		18	
Helium		2	
Attitude Control Gas		29	
Shroud System		411	
Separable			
1. Nose fairing	355		
2. V-band assembly	19		
Non-separable			
1. Diaphragm and shroud adapter	37*		

*Note: This value does not include any weight for the spacecraft adapter.

E-3236-4

E-3236-4

Table 2-5 (Cont.)

AGENA SPACECRAFT SUPPORT		24
C-Band Beacon and Adapter Kit	7	
Fusistor J-Box	1	
Aux. TM Adapter Kit	4	
C-Band Coax Cable	1	
Secondary Umbilical Installation	5	
Instr. Meas. Points	5	
DC Relays	1	
TOTAL AGENA D EMPTY WEIGHT		2, 160
PROPELLANTS		13, 521
Total Impulse Propellants	13, 343	
Non-Impulse Propellants	55	
Residual Propellants	48	
Performance Reserve Propellants	75	
SYSTEMS CONTINGENCY AS HARDWARE WEIGHT		38
GROSS AGENA WEIGHT (minus payload but including Agena S/C Support)		15, 719
DROP WEIGHTS		-789
Booster Adapter	-281	
Booster Adapter Extension	-90	
Booster Adapter Extension Ring	-10	
Detonator and Charge	-1	
Horizon Sensor Fairings	-7	
Spacecraft Shroud and V-band	-374	
Shroud Wire	-1	
Retro-Rockets	-10	
Starter Grains	-2	
Attitude Control Gas	-13	

Table 2-5 (Cont.)

IMPULSE PROPELLANTS		-13,343
NON-IMPULSE PROPELLANTS		-55
AGENA ON ORBIT		1,532
Performance Reserve Propellants	75	
Residual Propellants	48	
Systems Contingency	38	
Inert Agena Weight	1,371	

E-3236-4

E-3236-4

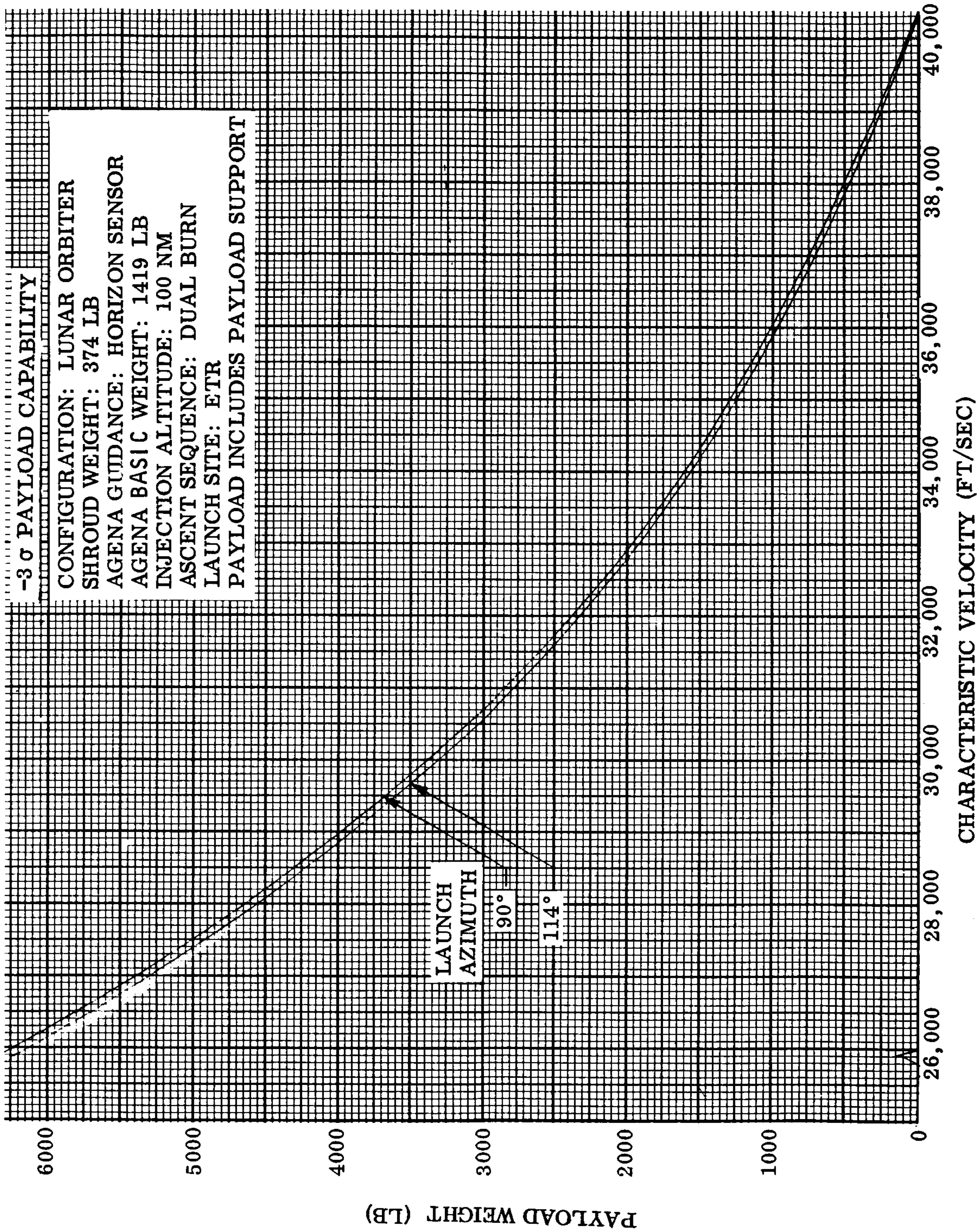


Fig. 2-2 Payload Vs. Characteristic Velocity, Lunar Orbiter Type Equipment

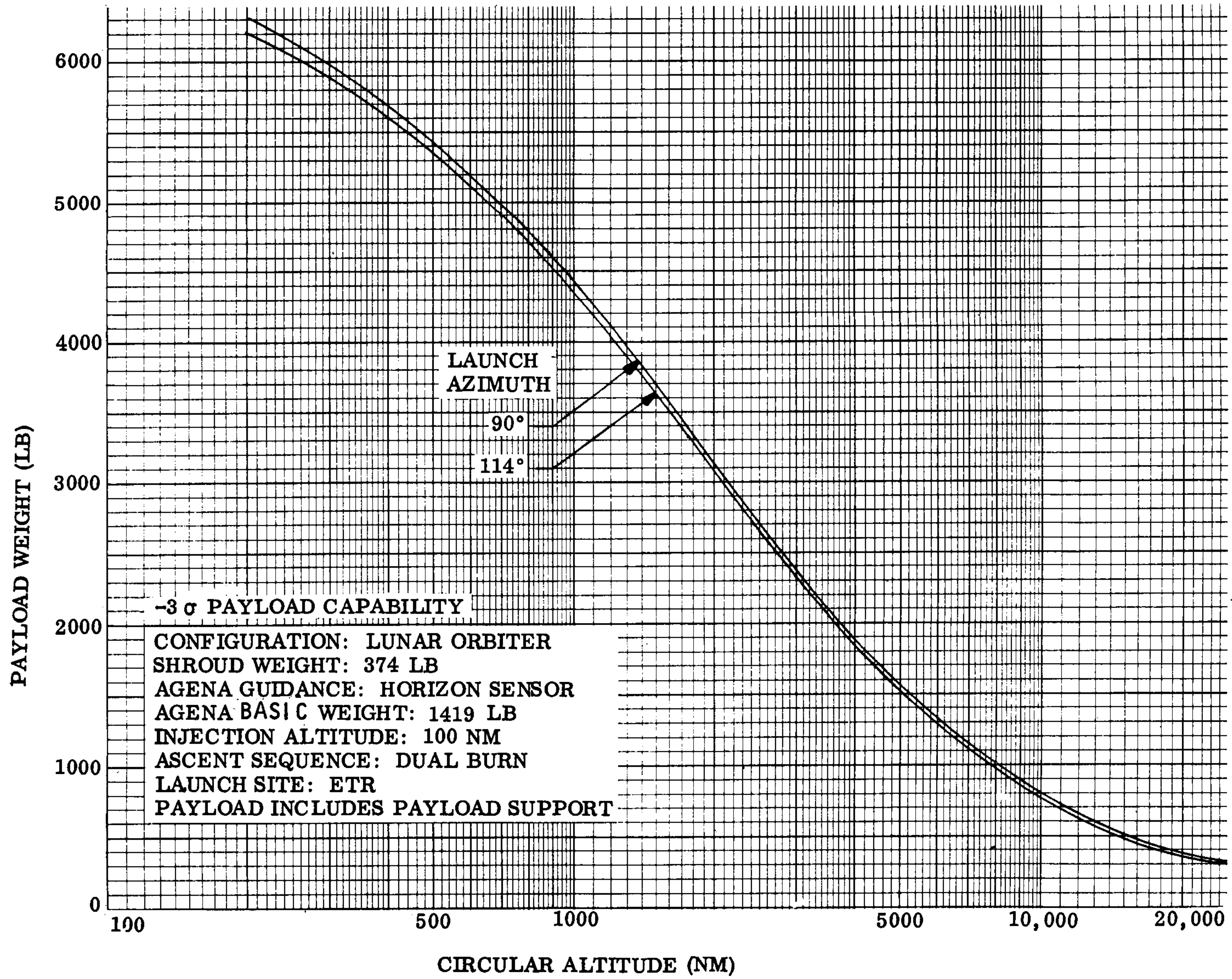


Fig. 2-3 Payload Vs. Circular Orbit Altitude, Lunar Orbiter Type Equipment

E-3236-4

[redacted]

E-3236-4

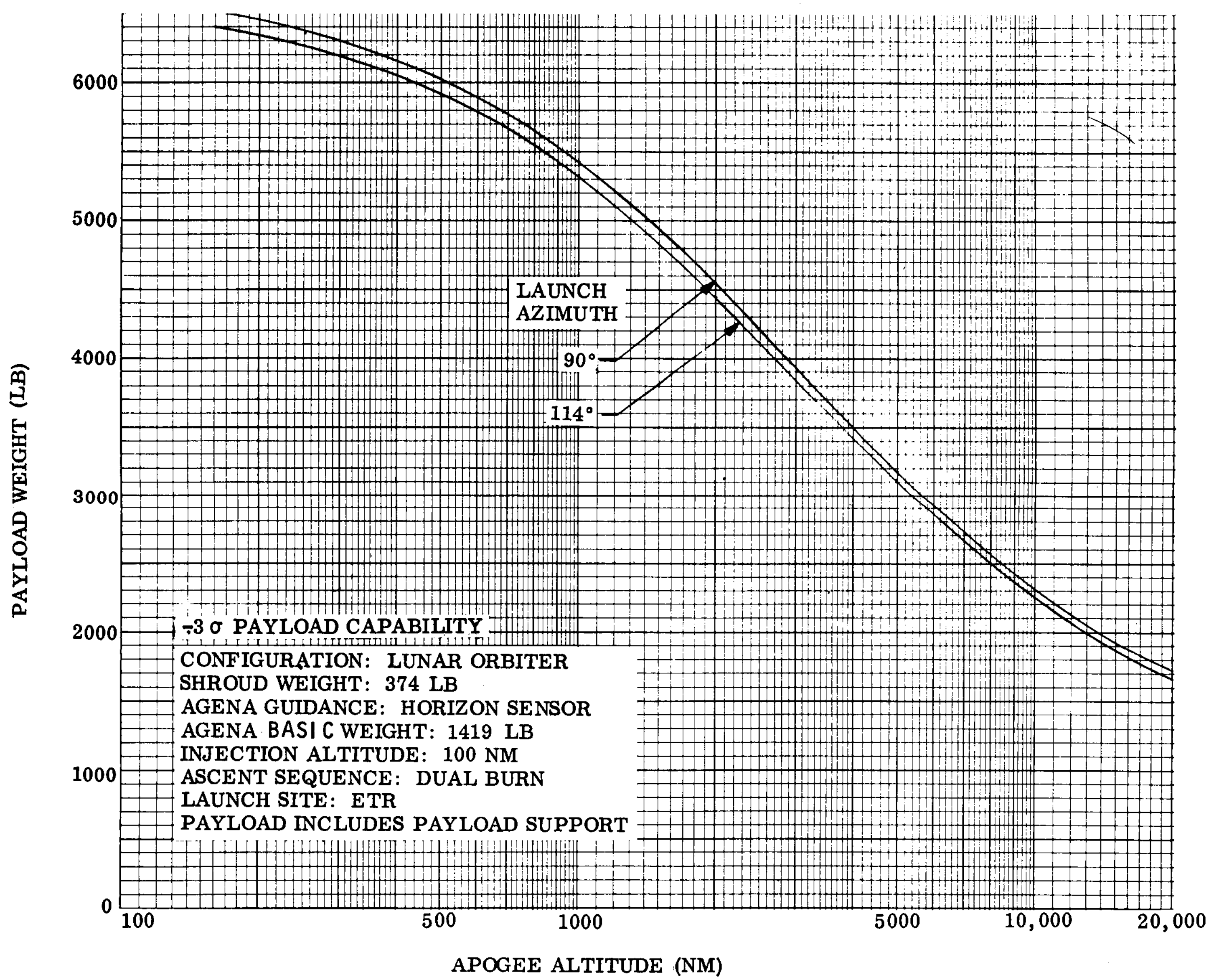


Fig. 2-4 Payload Vs. Elliptical Orbit Apogee, Lunar Orbiter Type Equipment

[redacted]

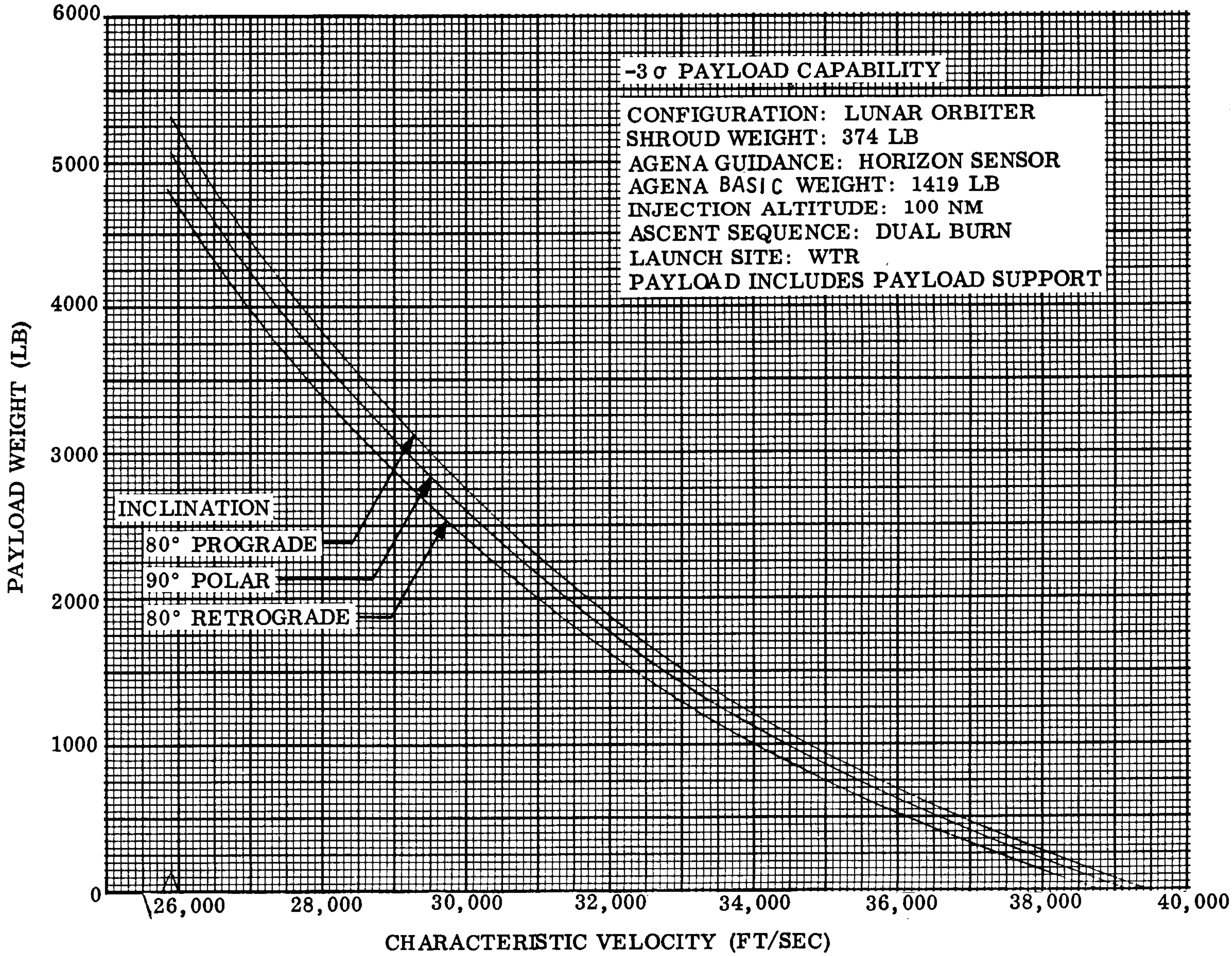


Fig. 2-5 Payload Vs. Characteristic Velocity, Lunar Orbiter Type Equipment

E-3236-4

E-3236-4

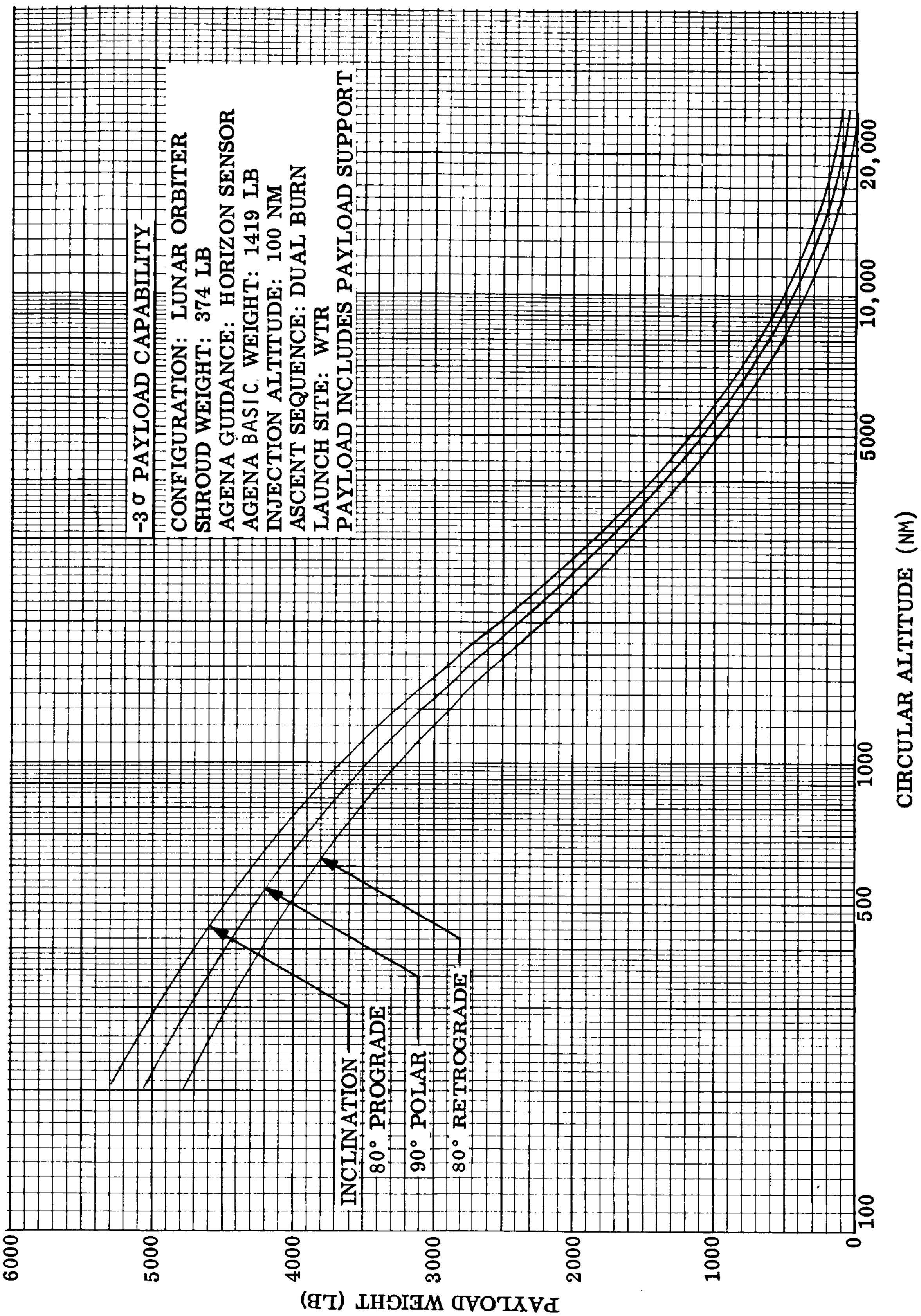


Fig. 2-6 Payload Vs. Circular Orbit Altitude, Lunar Orbiter Type Equipment

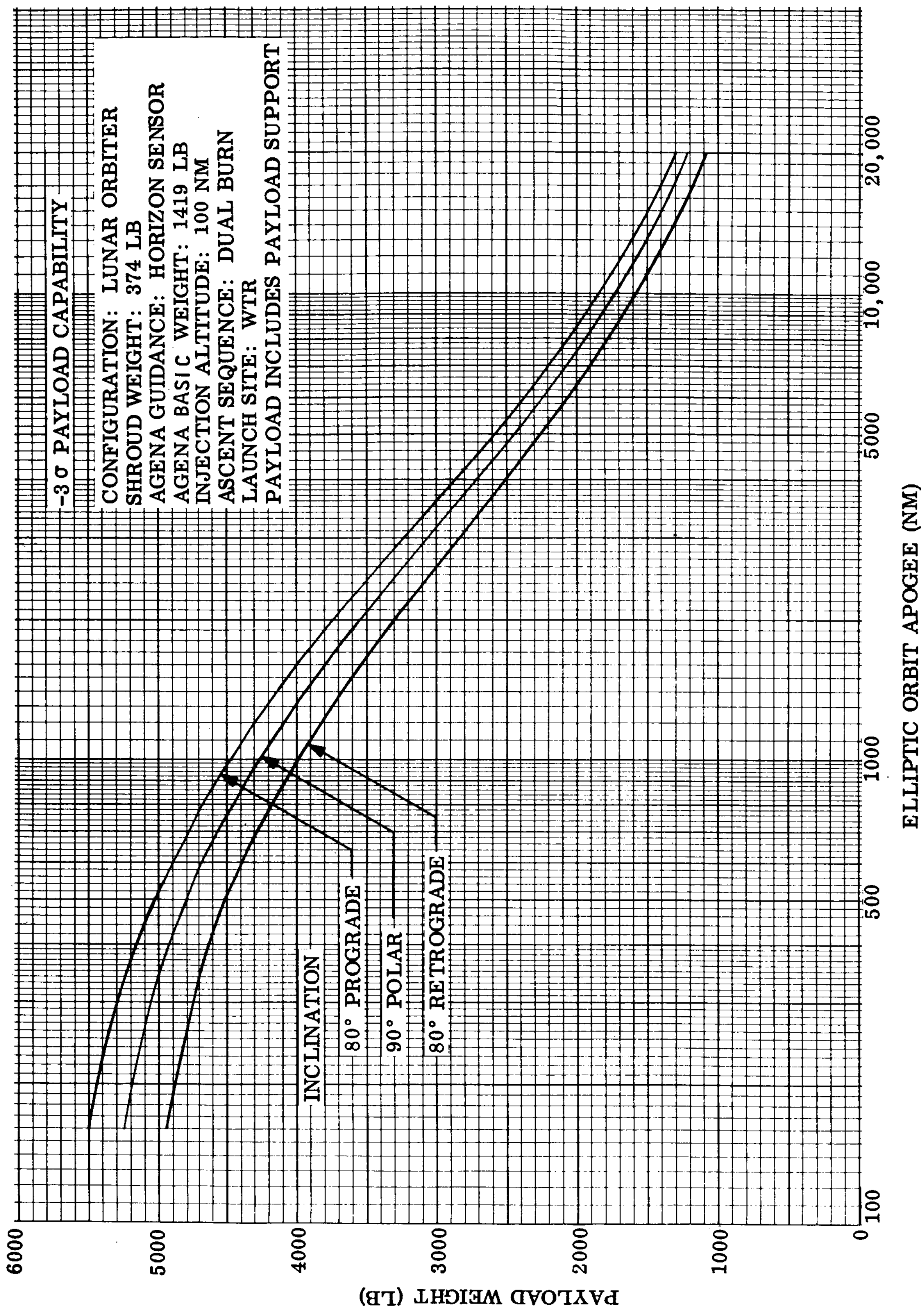


Fig. 2-7 Payload Vs. Elliptical Orbit Apogee, Lunar Orbiter Type Equipment

E-3236-4

E-3236-4

2.4.2 EOGO Type Equipment

The weight breakdown and weight sequence for the Agena used with the Atlas Booster vehicle is shown in Table 2-6, Typical EOGO Type Agena D Weight Summary (Atlas Booster with Standard Agena Clamshell Shroud).

The performance data are presented for the vehicle configuration as follows for the indicated launch site:

Figure	Launch Site	Description
2-8	ETR	Payload vs. Characteristic Velocity, EOGO Type Equipment
2-9	ETR	Payload vs. Circular Altitude, EOGO Type Equipment
2-10	ETR	Payload vs. Elliptical Orbit Apogee, EOGO Type Equipment
2-11	ETR	Payload vs. Apogee Altitude (For Perigee altitude of 200, 300, 400 nm), EOGO Type Equipment
2-12	WTR	Payload vs. Characteristic Velocity, EOGO Type Equipment
2-13	WTR	Payload vs. Circular Orbit Altitude, EOGO Type Equipment
2-14	WTR	Payload vs. Elliptical Orbit Apogee, EOGO Type Equipment

Table 2-6

TYPICAL EOGO TYPE AGENA D WEIGHT SUMMARY

(Atlas Booster With Standard Agena Clamshell Shroud)

AGENA D COMMITTED WEIGHT EMPTY			1,496
REMOVALS			-33
Self Destruct Items		-20	
Shorting Connectors		-1	
Pressured RF Switch		-2	
Coax Cables		-2	
Sequence Timer		-8	
OPTIONALS			177
Battery Kit Type 4 (2)		32	
Flight Control Patch Panel Kit		1	
Sequence Timer (Wired)		8	
Safe Arm and Plug		1	
Booster Adapter Extension Kit		90	
Booster Adapter Extension Ring Kit		10	
Command Destruct		35	
PECULIARS			756
Standard Agena Clamshell Shroud		695	
Separable			
1. Nose Fairing	578		
2. Thermal Shield	52		
3. V-band Assembly	19		
Non-separable			
1. Diaphragm and shroud Adapter ring	46*		
Transducers		9	
Wiring and Connectors		17	
DC Relays		1	
Helium		2	
Attitude Control Gas		29	
Misc. Brackets		3	

*Note: This value does not include any weight for the spacecraft adapter.

E-3236-4

E-3236-4

Table 2-6 (Cont.)

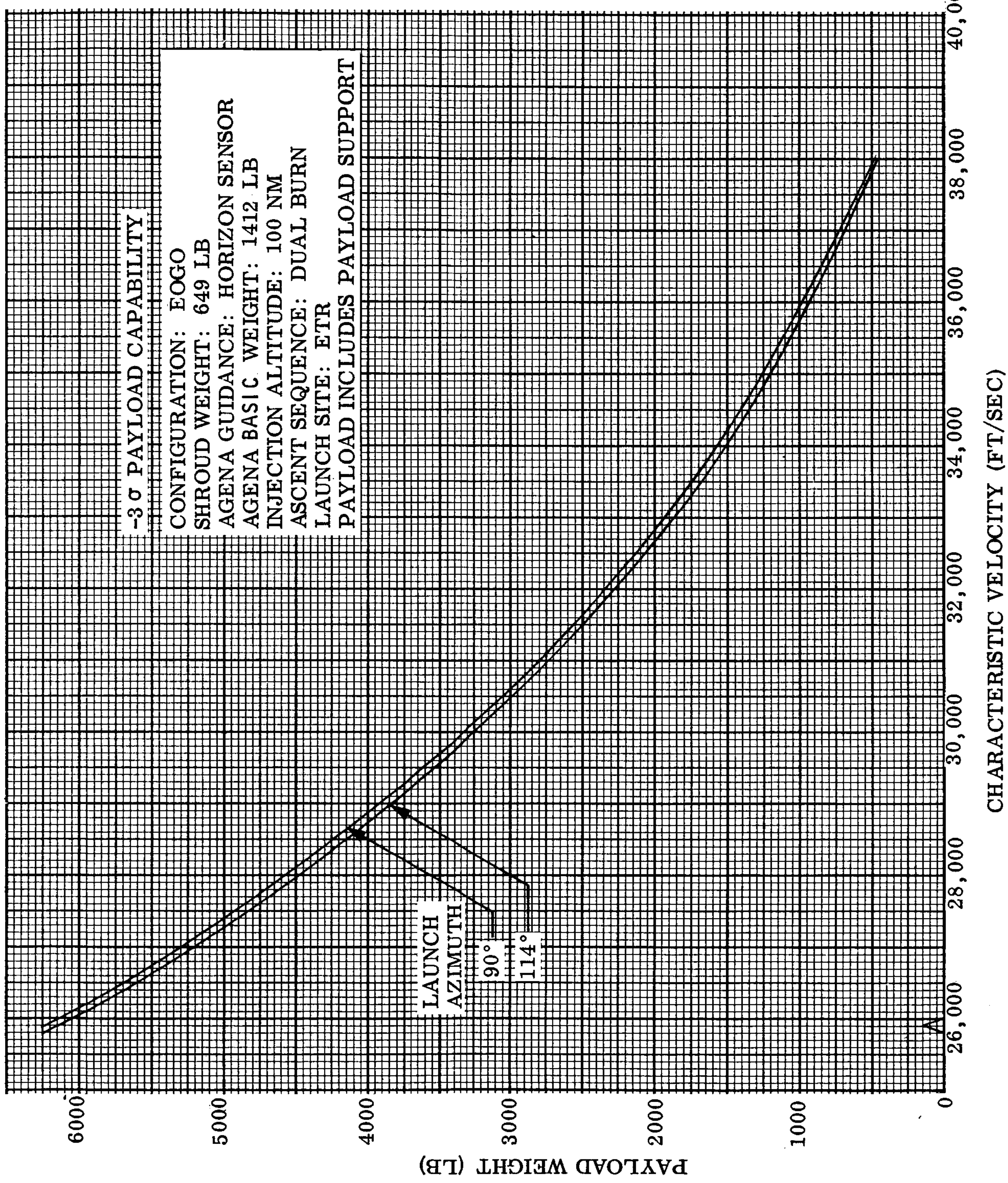
AGENA SPACECRAFT SUPPORT		30
Payload Attach Bolts	1	
C-Band Beacon Adapter Kit Plus Beacon	10	
Type 5 TM Kit 2 Watt	2	
Fusistor J-Box	1	
Aux. TM Adapter Kit	4	
DC/DC Converters	2	
Ring Plus Bolts	10	
TOTAL AGENA D EMPTY WEIGHT		2,426
PROPELLANTS		13,521
Usable Impulse Propellants	13,343	
Non-Impulse Propellants	55	
Residual Propellants	48	
Performance Reserve Propellants	75	
SYSTEMS CONTINGENCY AS HARDWARE WEIGHT		38
GROSS AGENA WEIGHT (Minus payload, including Agena S/C Support)		15,985
DROP WEIGHTS		-1,062
Booster Adapter	-279	
Booster Adapter Extension	-90	
Booster Adapter Extension Ring	-10	
Detonator and Charge	-1	
Horizon Sensor Fairings	-7	
S/C Shroud and Attach	-649	
Starter Grains	-2	
Attitude Control Gas	-14	
Retro-rockets	-10	

Table 2-6 (Cont.)

IMPULSE PROPELLANTS		-13,343
NON-IMPULSE PROPELLANTS		-55
AGENA ON ORBIT		1,525
Performance Reserve Propellants	75	
Residual Propellants	48	
System Contingency	38	
Inert Agena Weight	1,364	

E-3236-4

E-3236-4


−3 σ PAYLOAD CAPABILITY
CONFIGURATION: EOGO
SHROUD WEIGHT: 649 LB
AGENA GUIDANCE: HORIZON SENSOR
AGENA BASIC WEIGHT: 1412 LB
INJECTION ALTITUDE: 100 NM
ASCENT SEQUENCE: DUAL BURN
LAUNCH SITE: ETR
PAYLOAD INCLUDES PAYLOAD SUPPORT
LAUNCH AZIMUTH
90°
114°
PAYLOAD WEIGHT (LB)
0
1000
2000
3000
4000
5000
6000
CHARACTERISTIC VELOCITY (FT/SEC)
26,000
28,000
30,000
32,000
34,000
36,000
38,000
40,000

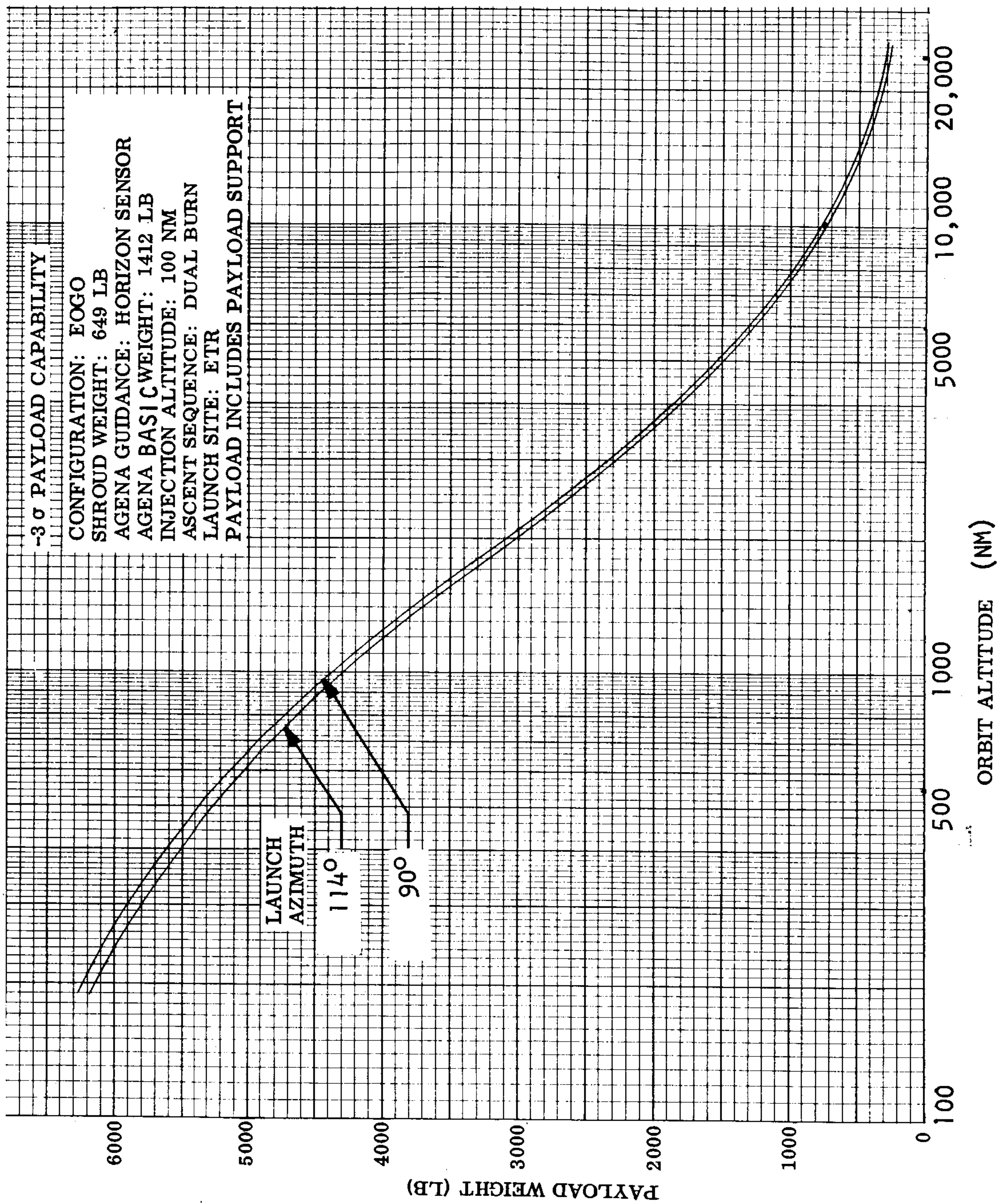


Fig. 2-9 Payload Vs. Circular Orbit Altitude, EOGO Type Equipment

E-3236-4

E-3236-4

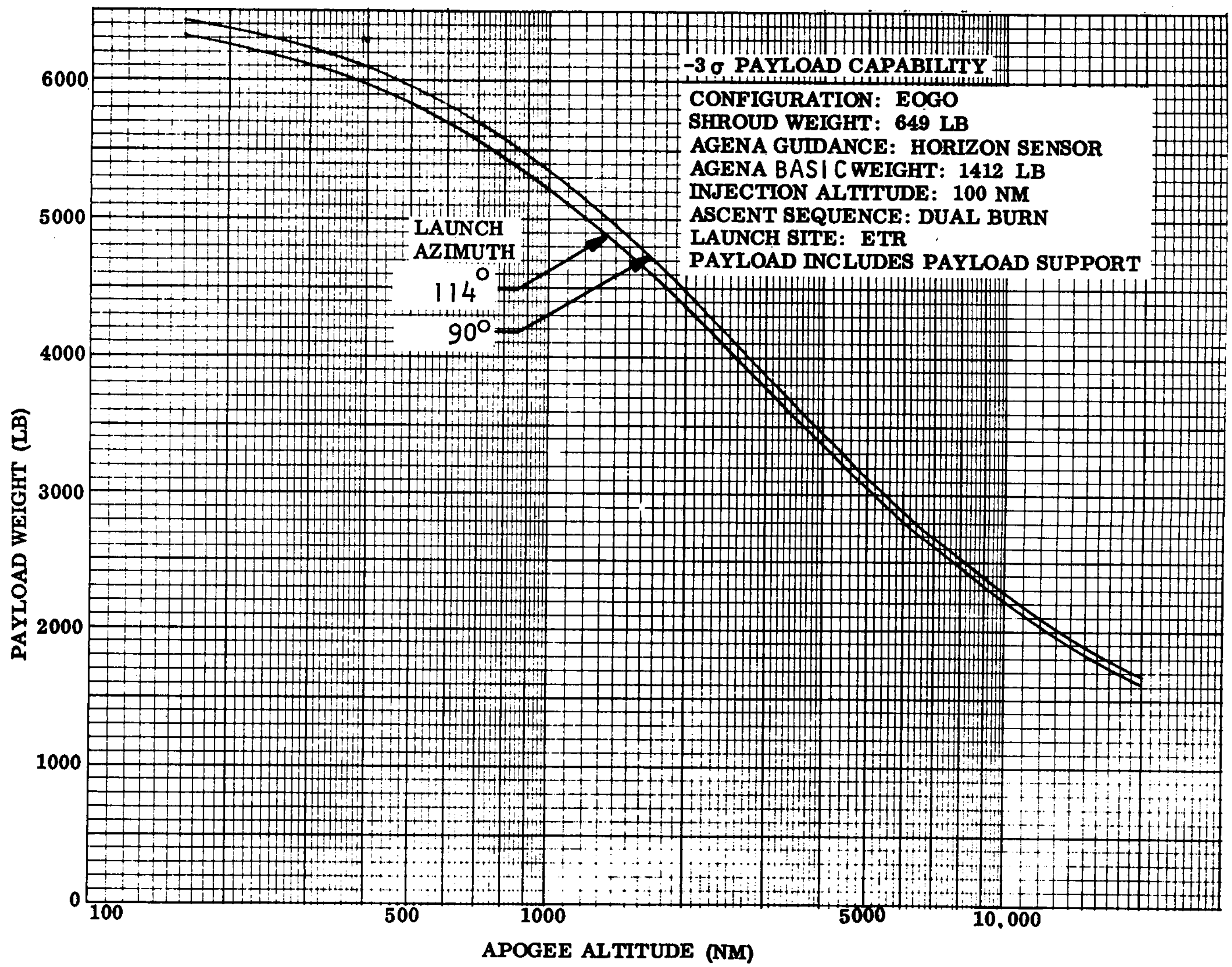
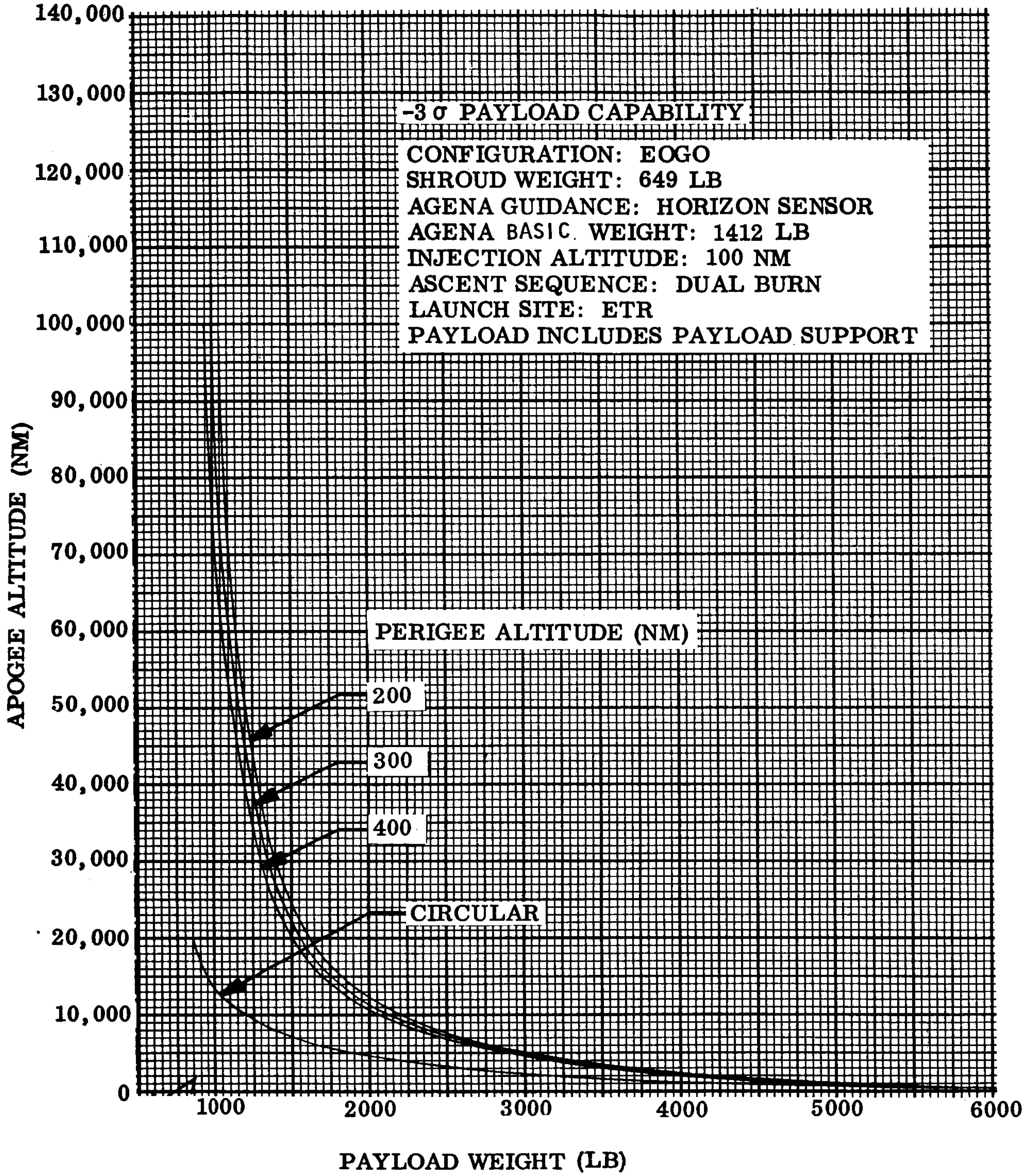


Fig. 2-10 Payload Vs. Elliptical Orbit Apogee, EOGO Type Equipment



E-3236-4

Fig. 2-11 Payload Vs. Apogee Altitude (For Perigee Altitudes of 200, 300, and 400 nm), EOGO Type Equipment

E-3236-4

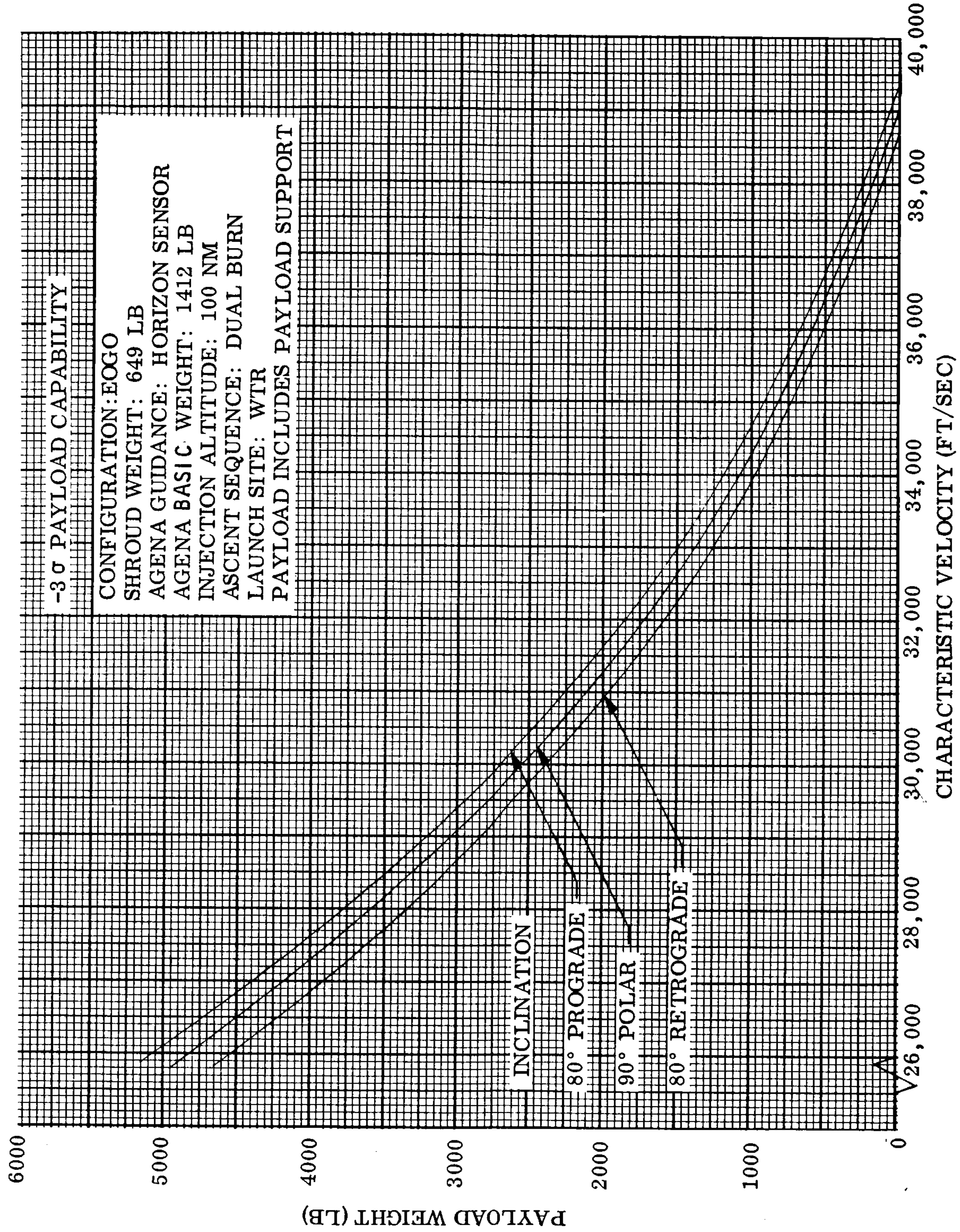


Fig. 2-12 Payload Vs. Characteristic Velocity, EOGO Type Equipment

[redacted]

E-3236-4

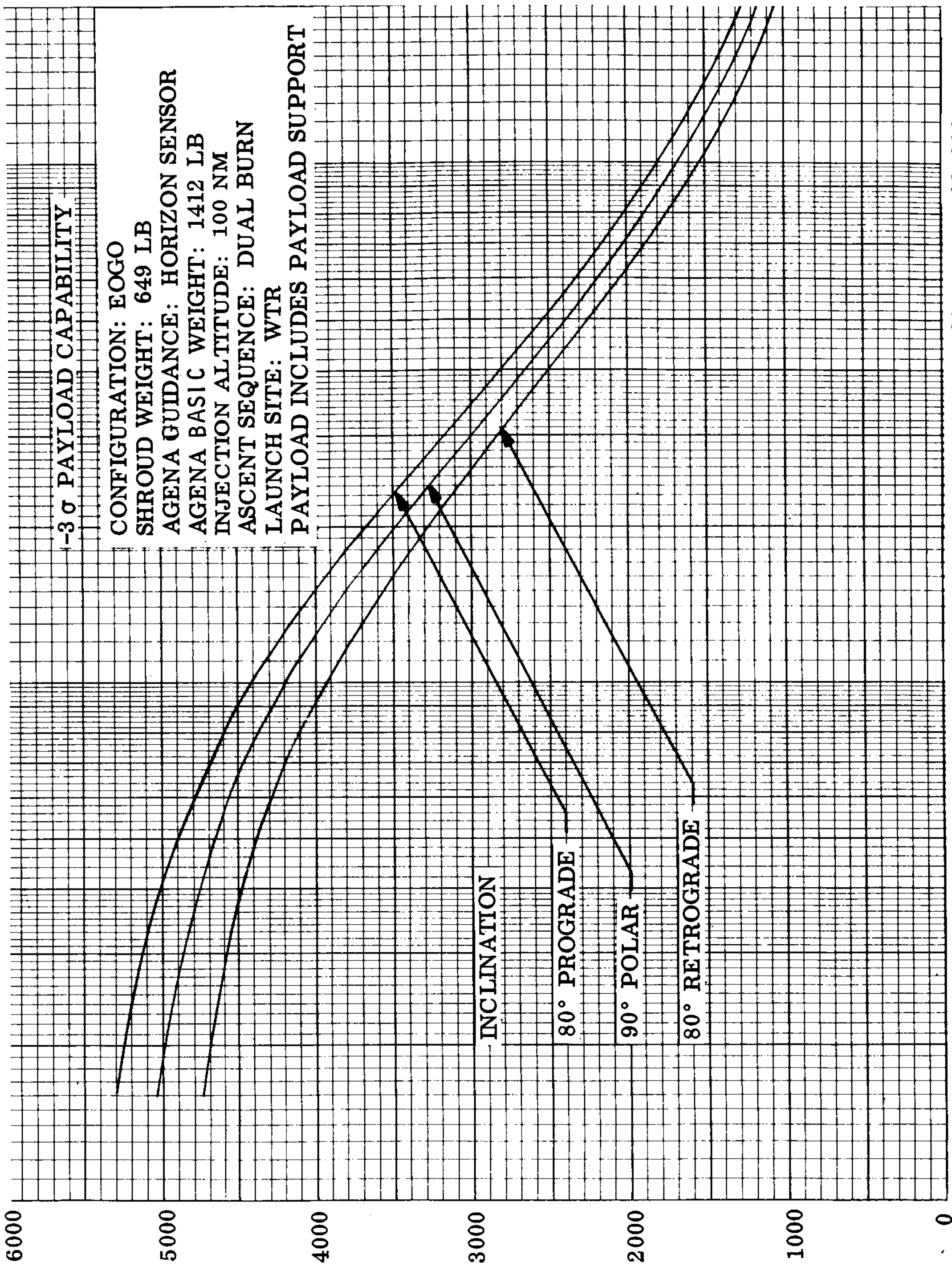


Fig. 2-13 Payload Vs. Circular Orbit Altitude, EOGO Type Equipment

E-3236-4

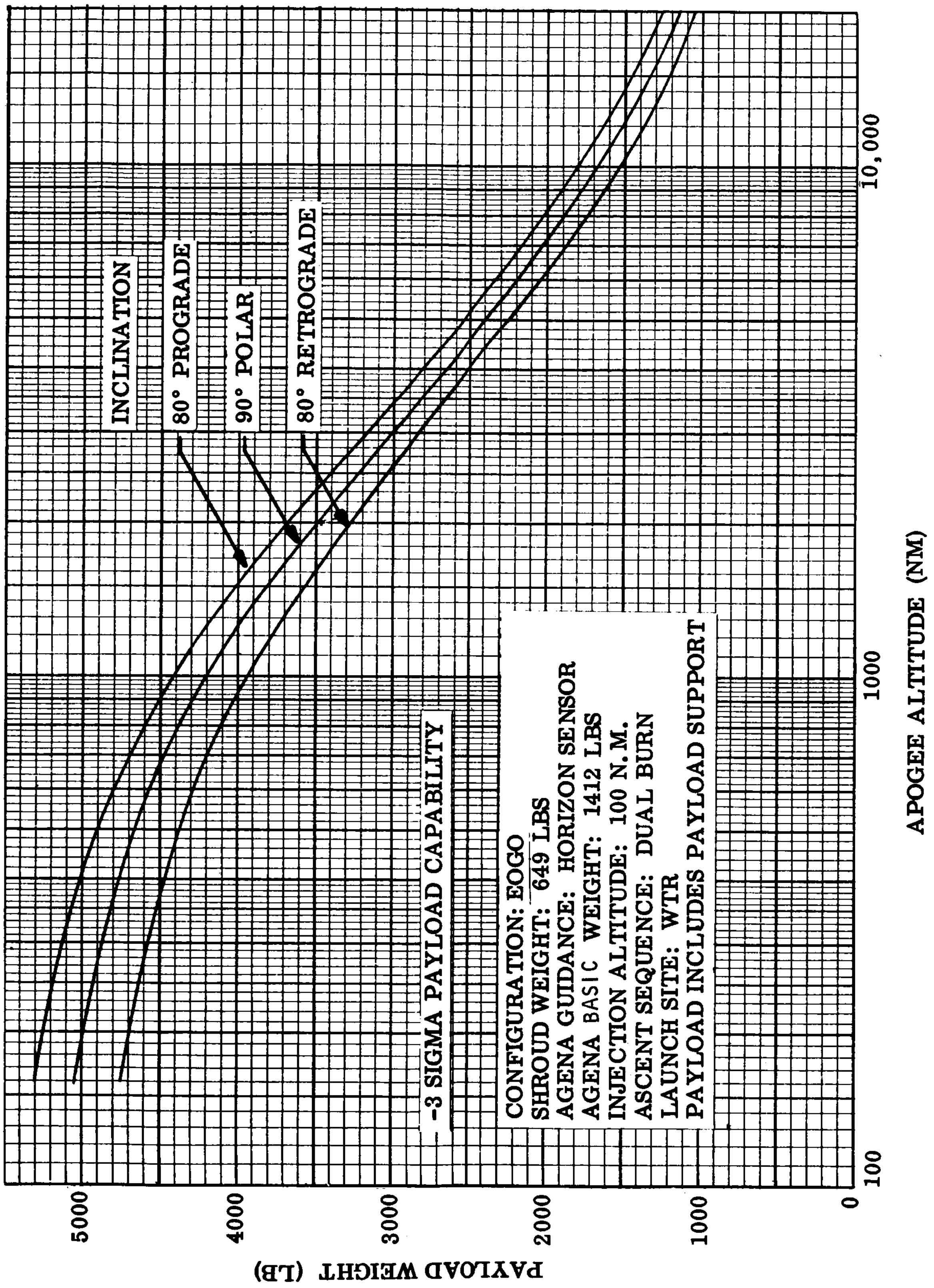


Fig. 2-14 Payload Vs. Elliptical Orbit Apogee, EOGO Type Equipment

E-3236-4

2.4.3 OAO Type Equipment

The weight breakdown and weigh sequence for the Agena used with the Atlas Booster vehicle is shown in Table 2-7, Typical OAO Type Agena D Weight Summary (Atlas Booster).

The performance data are presented for the vehicle configuration as follows for the indicated launch site:

Figure	Launch Site	Description
2-15	ETR	Payload vs. Characteristic Velocity, OAO Type Equipment
2-16	ETR	Payload vs. Circular Orbit Altitude, OAO Type Equipment
2-17	ETR	Payload vs. Elliptical Orbit Apogee, OAO Type Equipment
2-18	WTR	Payload vs. Characteristic Velocity, OAO Type Equipment
2-19	WTR	Payload vs. Circular Orbit Altitude, OAO Type Equipment
2-20	WTR	Payload vs. Elliptical Orbit Apogee, OAO Type Equipment

E-3236-4

Table 2-7

TYPICAL OAO TYPE AGENA D WEIGHT SUMMARY (ATLAS BOOSTER)

AGENA D COMMITTED WEIGHT EMPTY			1496
Removals			
Air Cooling Door		- 1	
Booster Adapter		-282	
Umbilical Door		- 1	
Self Destruct Items		- 20	
Battery Tie Bolts and Shorting Connectors		- 1	
Wiring and Connectors		- 1	
Booster Retro-Rockets		- 10	
Sequence Timer		- 8	
Beryllium Doors		- 27	
Optionals			98
Command Destruct		34	
TM Orbit Ant. Swit. Kit		1	
Battery Kit Type (2) VI		52	
Flt. Control Patch Panel Kit		1	
TM Transmitter and Adapter Kit		2	
Sequence Timer (Wired)		8	
Peculiars			4166
Fragmentation Shield		24	
Wiring and Connectors		30	
Air Cond. Duct and Coupling		2	
Booster Adapter		228	
Shroud System		1905	
1. Separable - Nose Fairing	1873		
2. Non-separable	32		
Mid Fairing and Restraining Struts GD/C		938	
Aft Fairing GD/C		902	
Engine Drain and Fume Detection Lines		1	
Transducers and Brackets		10	

E-3236-4

Table 2-7 (Cont.)

Distribution Connectors	2	
Parasitic VHF Antenna	3	
Helium	2	
Attitude Control Gas	29	
C-Band Beacon Parasitic Antenna	1	
Umbilical Chute Triplex	16	
UDMH Fill Chute	5	
IRFNA Fill Chute	5	
S/C Helium and Nitrogen Chute Duplex	12	
Nitrogen Fill Chute	6	
Shorting Connectors (6)	1	
Magnesium Doors and Panels	44	
AGENA SPACECRAFT SUPPORT		81
S/C Adapter Ring	19	
Payload Attach. Bolts	2	
C-Band Beacon Adapter Kit and Beacon	10	
Beacon Orbit Antenna R. F. Switch Kit	4	
S/C Nitrogen Fill System	2	
Coax - RF to Parasitic Ant.	1	
VHF Multicplr. Adapt. Kit	3	
Fusistor J-Box (2)	2	
RF Quick Disconnect	1	
Shorting Connectors	1	
DC-DC Converter	8	
Aux. TM Adapter Kit and Oscillator	3	
Power Control Unit	5	
Voltage Control Oscillators	3	
Chassis Assy. (2)	5	
Switch and Cal Unit (2)	2	
Oscillator Input Unit (2)	2	
Oscillator Tray and Cover	2	

Table 2-7 (Cont.)

TM Control J-Box	2	
TM Transmitter and Adapter Kit 2W (2)	4	
TOTAL AGENA D EMPTY WEIGHT		5490
Propellants		
Total Impulse Propellants	13319	
Non-Impulse Propellants	55	
Residual Propellants	48	
Performance Reserve Propellants	99	
SYSTEMS CONTINGENCY		38
GROSS AGENA WEIGHT (Minus payload but including Agena S/C Support)		19049
DROP WEIGHTS		-4039
Nitrogen Fill Chute	- 6	
Booster Adapt. & Attach.	-228	
Umbil. Chute Triplex	- 16	
Detonator and Charge	- 1	
Oxidizer Chute	- 5	
Fuel Chute	- 5	
Parasitic C-Band Beacon Antenna	- 1	
S/C and Nitrogen Chute Duplex	- 12	
Parasitic VHF Antenna	- 3	
Horizon Sensor Fairings	- 7	
Nose Fairing	-1873	
Forward Drain and Fume Detection	- 1	
Mid Fairing	-938	
Aft Fairing	-902	
Air Conditioning Duct and Coupling	- 2	
Fragmentation Shield	- 24	
Attitude Control Gas	- 13	
Starter Grains	- 2	
IMPULSE PROPELLANTS		-13319

E-3236-4

E-3236-4

Table 2-7 (Cont.)

NON-IMPULSE PROPELLANTS		-55
AGENA ON ORBIT		1636
Performance Reserve Propellants	99	
Residual Propellants	48	
System Contingency	38	
Inert Agena Weight	1451	

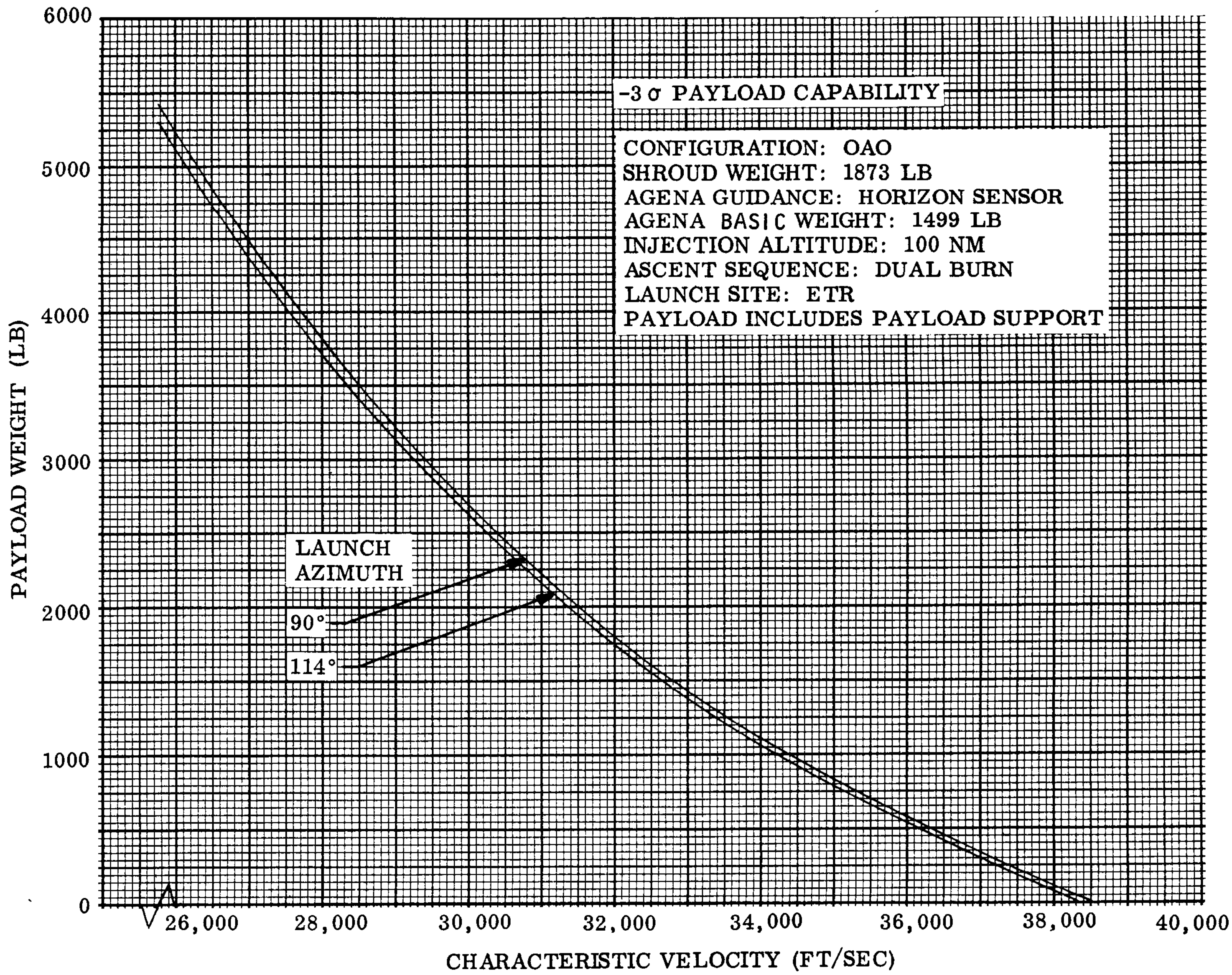


Fig. 2-15 Payload Vs. Characteristic Velocity, OAO Type Equipment

E-3236-4

E-3236-4

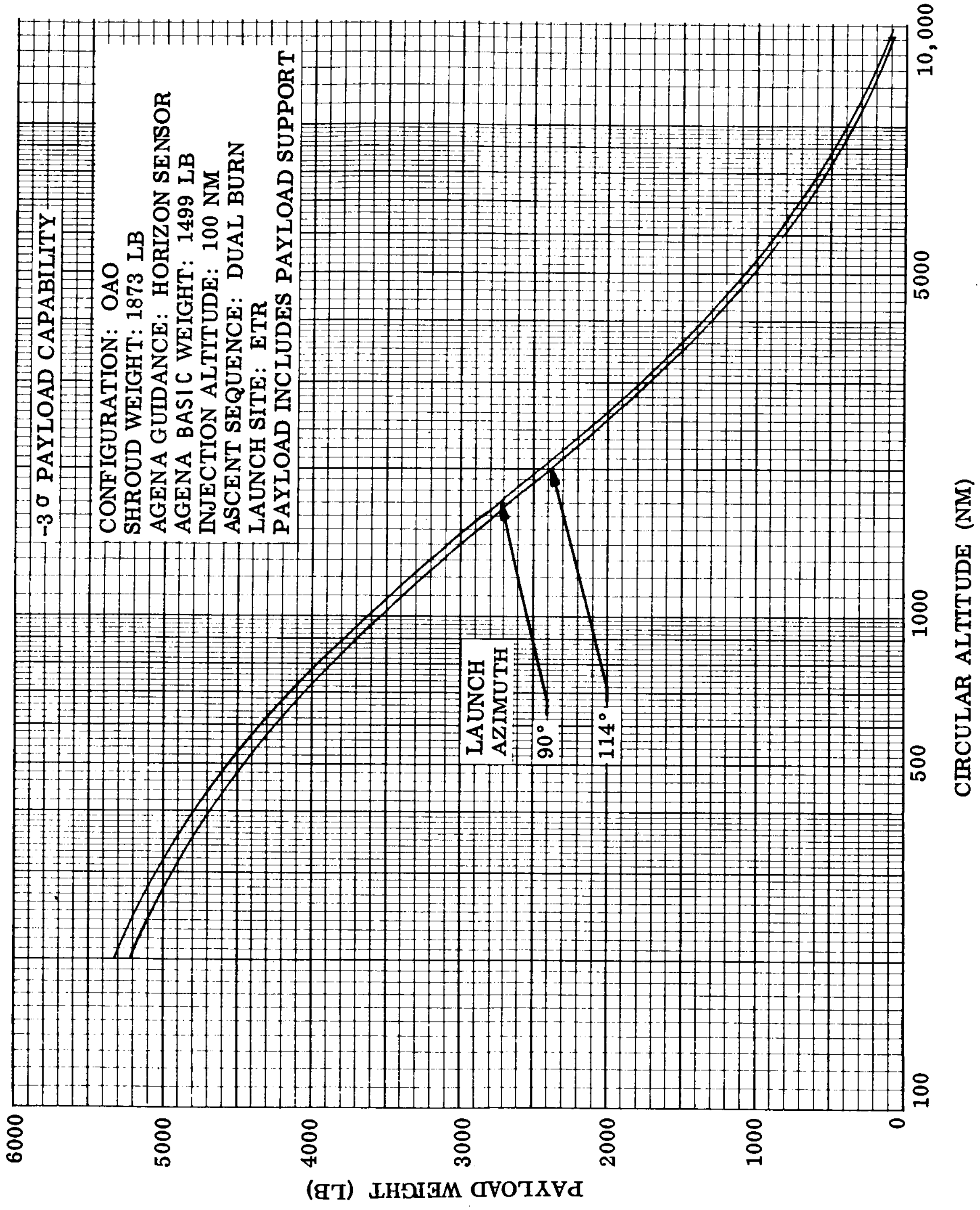


Fig. 2-16 Payload Vs. Circular Orbit Apogee, OAO Type Equipment

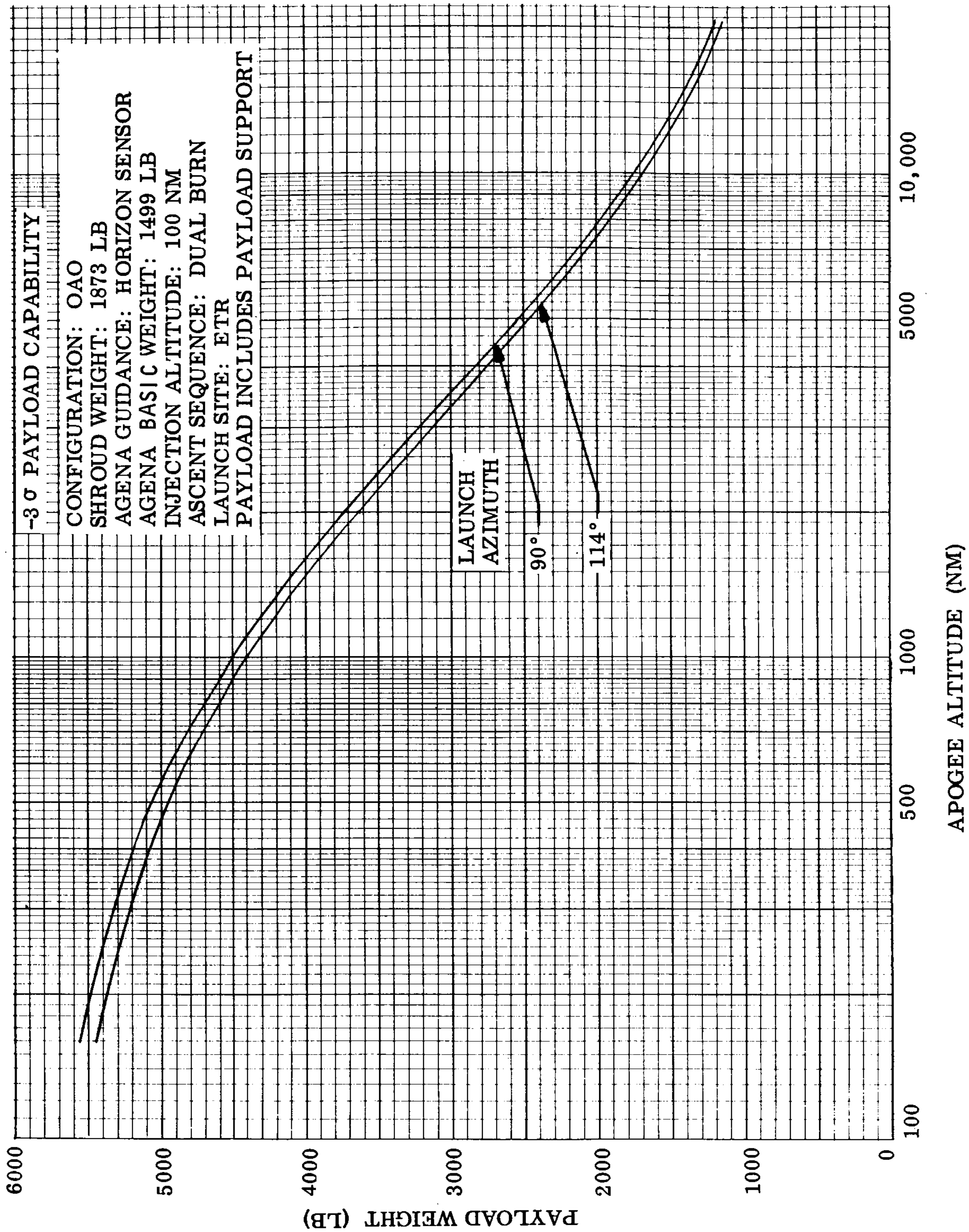


Fig. 2-17 Payload Vs. Elliptical Orbit Apogee, OAO Type Equipment

E-3236-4

E-3236-4

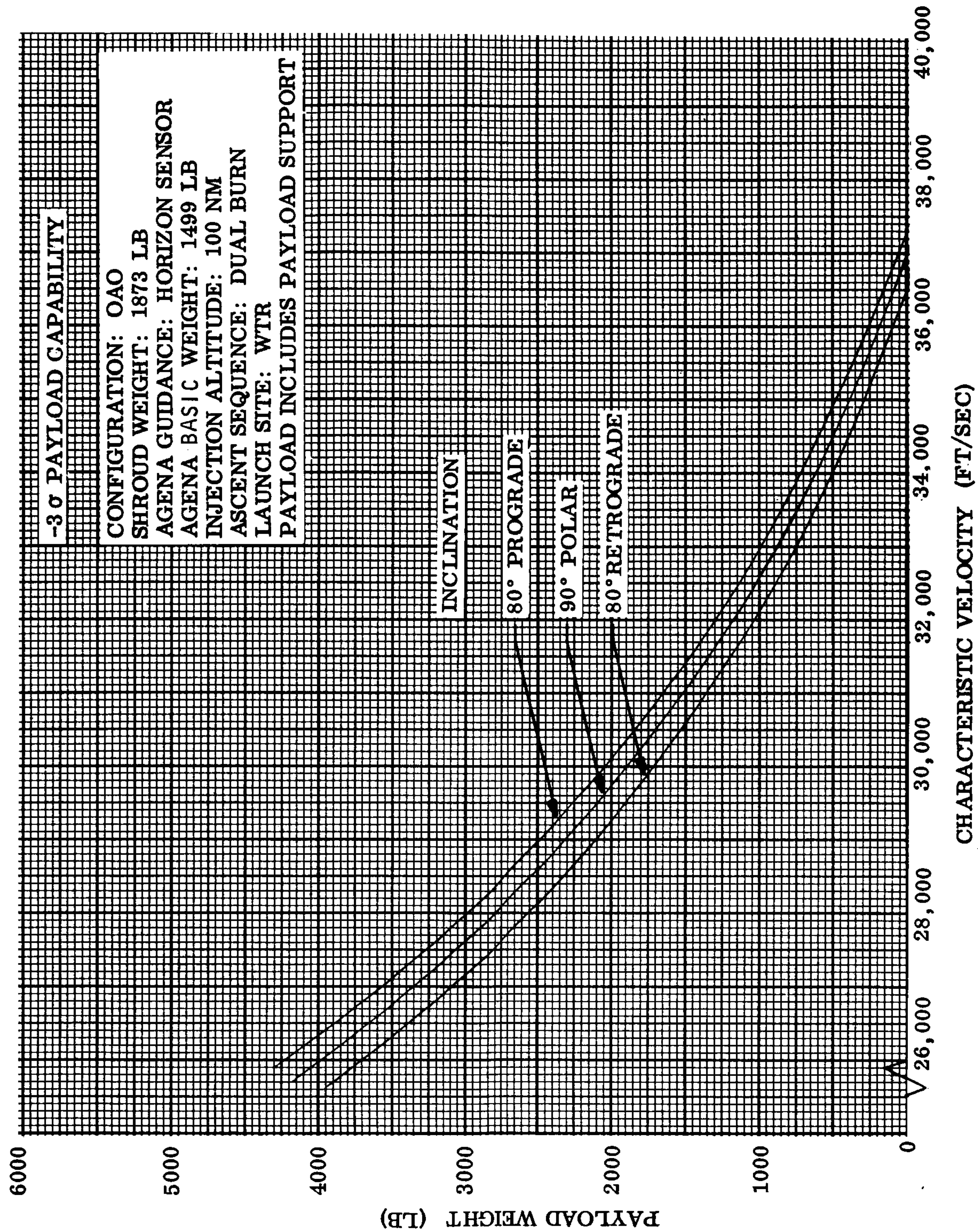


Fig. 2-18 Payload Vs. Characteristic Velocity, OAO Type Equipment

[redacted]

E-3236-4

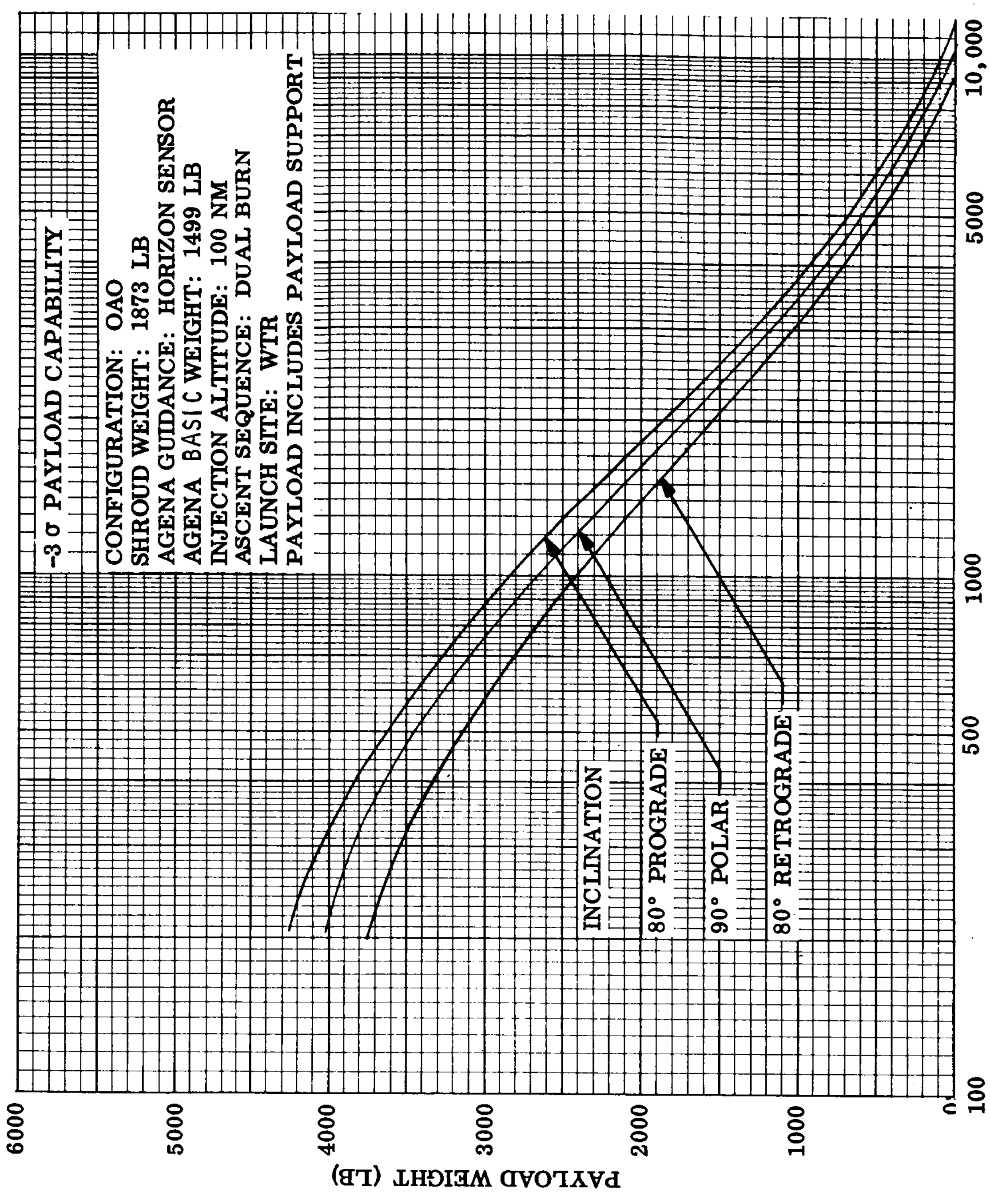


Fig. 2-19 Payload Vs. Circular Orbit Altitude, OAO Type Equipment

E-3236-4

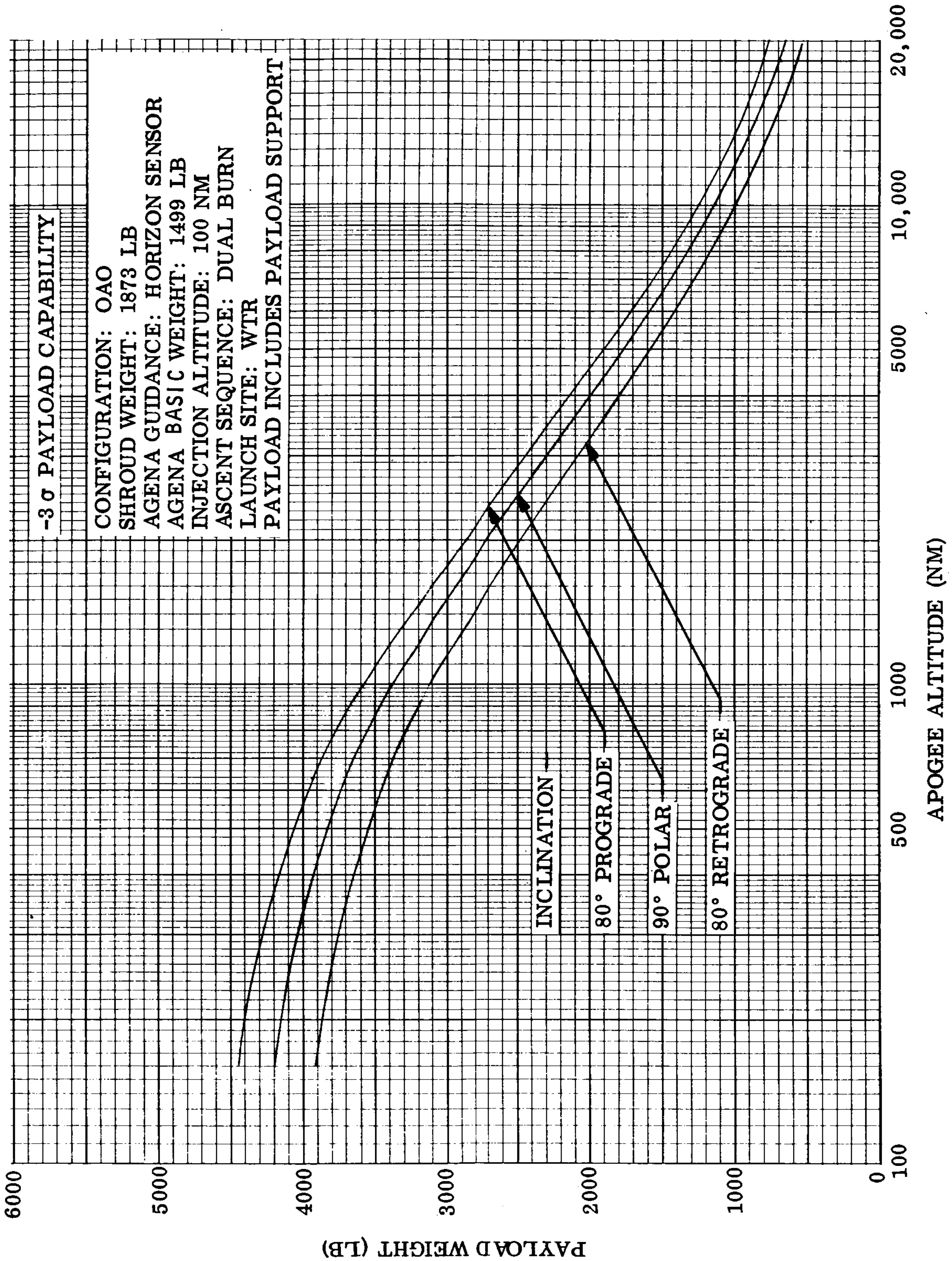


Fig. 2-20 Payload Vs. Elliptical Orbit Apogee, OAO Type Equipment

E-3236-4

2.5 PAYLOAD CAPABILITY–TAT/AGENA D

The payload curves for the TAT/Agena D have been generated in a manner similar to the Atlas/Agena D curves with a few exceptions. (See Par. 2.4). Only the WTR data has been generated, and here, information for dog-leg trajectories was available and therefore utilized in this document. For the TAT/Agena D, range safety constraints on launch azimuth result in dog-legs for inclinations lower than 84.2 deg prograde. The dog-leg maneuver is performed by the TAT booster autopilot and is initiated prior to BTL guidance at approximately 80 sec during which time a constant rate, open-loop yaw program is performed.

All the curves for the TAT booster utilize an 85-nm booster apogee and injection altitude with a dual burn Agena D configuration. The basic curve here is based on a series of six-degree-of-freedom trajectory runs made for 90-deg polar orbits. The weight summary of the TAT is presented in Table 2-8.

The capability plots are presented as functions of characteristic velocity,* circular orbit altitude, and elliptic orbit apogee for WTR launches. To facilitate computation of payload for elliptic orbits with perigee altitudes higher than 85 nm, Fig. 2-21 provides elliptic orbit conversion curves for perigee altitudes of 100, 200, 300, and 400 nm in terms of characteristic velocity for Agena dual burn. In addition, vis viva energy (C_3) for the aforementioned perigee altitude is shown as a function of characteristic velocity. Curves consider injection of the Agena at 85-nm perigee (first burn). A typical payload capability curve resulting from this conversion is shown in Fig. 2-25, which gives the TAT/Agena D POGO configuration in terms of apogee altitude for 100, 200, 300, and 400 nm.

Tolerances on the performance curves arise from deviations of the same sources mentioned in the Atlas/Agena D payload, see par. 2-4. An estimated tolerance of 10 and 25 lbs for the characteristic velocity and orbit altitude curves, respectively, should be considered.

*For definition of characteristic velocity, see Par. 2.4.

E-3236-4

Table 2-8

TYPICAL TAT (LV-2A) WEIGHT SUMMARY*

VEHICLE AT VECO		8064
Dry Weight Liquid Booster	6873	
Trapped Propellant	423	
Pressurization Gas	436	
Unused Lube Oil	52	
Residuals	280	
EXPENDABLES		199
Vernier Propellants	63	
Tail-Off Propellants	136	
MECO		8263
EXPENDABLES		55325
Lox	37127.9	
Fuel	18021.0	
Lube Oil Used	42.0	
Pressurization Gas Overboard	96.0	
Vernier Propellants Overboard	38.0	
VEHICLE AT SOLID BOOSTER SEPARATION		63588
DROP & EXPENDABLE WEIGHT		21874
Empty Motors	5652.0	
LOX	11014.3	
Fuel	5163.8	
Lube Oil Used	12.0	
Pressurization Gas Overboard	23.0	
Vernier Propellant Overboard	9.0	
VEHICLE AT SOLID BOOSTER BURNOUT		85462

*This weight summary was used for WTR launches.

Table 2-8 (Cont.)

EXPENDABLES		49976
Solid Fuel	22176.0	
LOX	18902.3	
Fuel	8876.1	
Lube Oil	21.2	
TOTAL FIRST STAGE WEIGHT AT LIFT OFF (Minus Agena & Spacecraft)		135438

E-3236-4

E-3236-4

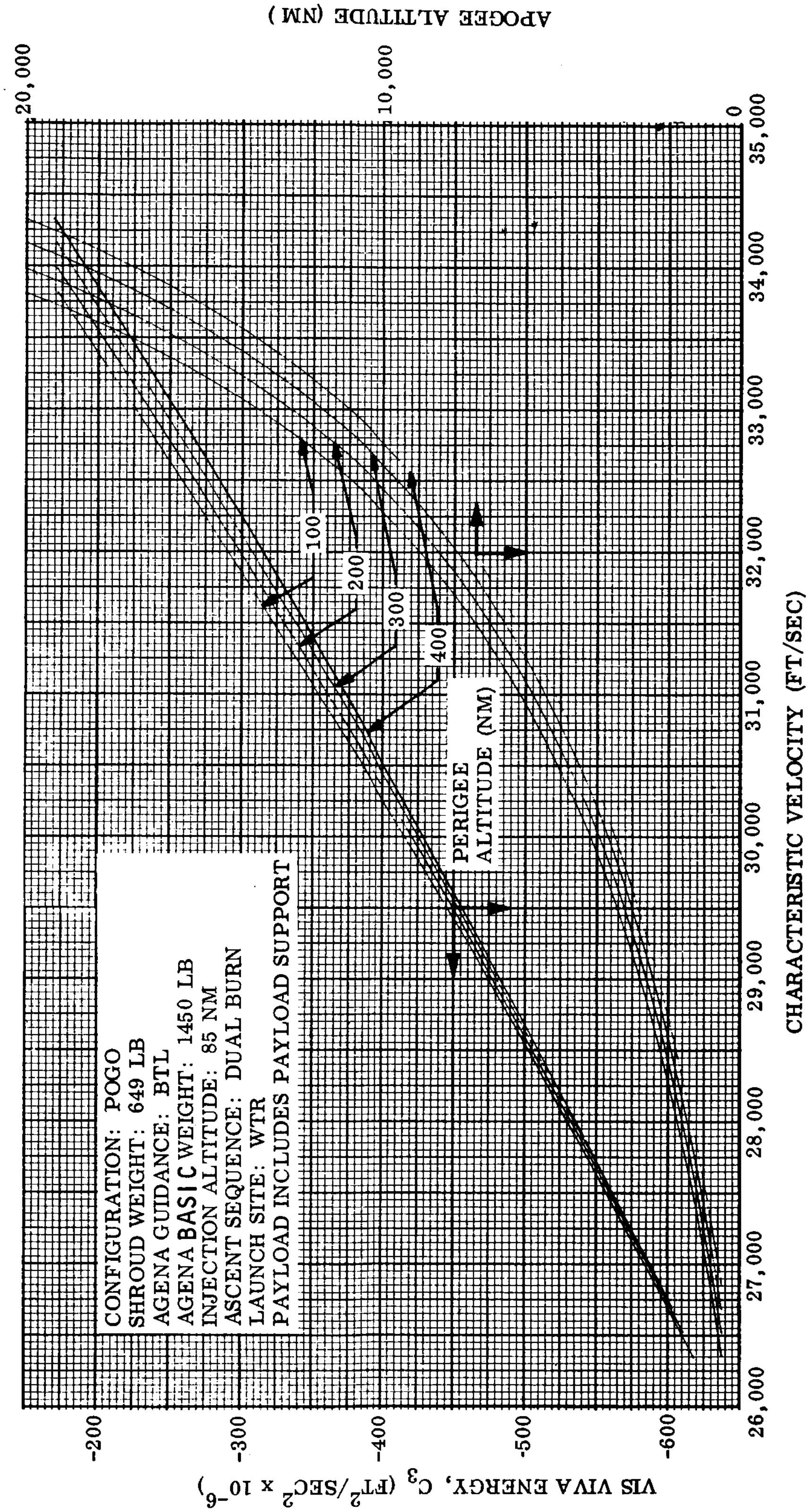


Fig. 2-21 Payload Vs. Apogee Altitude

E-3236-4

2.5.1 POGO Type Equipment

The weight breakdown and weight sequence for the Agena used with the TAT Booster vehicle is shown in Table 2-9, Typical POGO Type Agena D Weight Summary (TAT Booster with Standard Agena Clamshell Shroud and BTL in Agena).

The performance data are presented for the vehicle configuration as follows for the WTR launch site:

Figure	Description
2-22	Payload vs. Characteristic Velocity, POGO Type Equipment
2-23	Payload vs. Circular Orbit Altitude, POGO Type Equipment
2-24	Payload vs. Elliptical Orbit Apogee, POGO Type Equipment
2-25	Payload vs. Apogee Altitude (For Perigee Altitude of 100, 200, 300, and 400 nm), POGO Type Equipment

Table 2-9

TYPICAL POGO TYPE AGENA D WEIGHT SUMMARY
(TAT Booster with Standard Agena Clamshell Shroud and BTL in Agena)

AGENA D COMMITTED WEIGHT EMPTY			1496
REMOVALS			-21
Battery Tie Bolts		- 1	
Wiring and Connectors		- 3	
RF Switch		- 2	
BTL Removals		- 7	
Sequence Timer		- 8	
OPTIONALS			107
Battery Kit Type 4 (2)		32	
Flight Control Patch Panel Kit		1	
BTL Guidance Set		34	
BTL Adapter Kit		31	
Sequence Timer (Wired)		8	
Safe Arm and Plug		1	
PECULIARS			763
Standard Agena Clamshell Shroud		695	
Separable			
1. Nose Fairing	578		
2. Thermal Shield	52		
3. V-band Assy	19		
Non-separable			
1. Diaphragm and shroud adapter ring	46*		

*Note: This value does not include any weight for the spacecraft adapter.

E-3236-4

E-3236-4

Table 2-9 (Cont.)

Transducers	9	
Wiring and Connectors	17	
DC Relays	1	
Helium	2	
Attitude Control Gas	29	
Power Supply Type IX	7	
Misc. Brackets	3	
AGENA SPACECRAFT SUPPORT		30
Payload Attach Bolts	1	
C-Band Beacon Adapter Kit Plus Beacon	10	
Type V TM Kit 2 Watt	2	
Fusistor J-Box	1	
Aux. TM Adapter Kit	4	
DC/DC Converters	2	
Ring Plus Bolts	10	
TOTAL AGENA D EMPTY WEIGHT		2375
PROPELLANTS		13521
Total Usable Impulse Propellants	13313	
Non-Impulse Propellants	55	
Residual Propellants	48	
Performance Reserve Propellants	105	
SYSTEMS CONTINGENCY		38
GROSS AGENA WEIGHT (Minus Spacecraft but including Agena S/C support)		15934
DROP WEIGHTS		-973
Booster Adapter	-279	
Detonator and Charge	- 1	
Horizon Sensor Fairing	- 7	
Shroud and attachments	-649	
Starter Grains	- 2	

Table 2-9 (Cont.)

Attitude Control Gas	- 14	
Retro-Rockets	- 10	
Self Destruct	- 11	
IMPULSE PROPELLANTS		-13313
NON-IMPULSE PROPELLANTS		-55
AGENA ON ORBIT		1593
Performance Reserve Propellants	105	
Residual Propellants	48	
System Contingency	38	
Inert Agena Weight	1402	

E-3236-4

E-3236-4

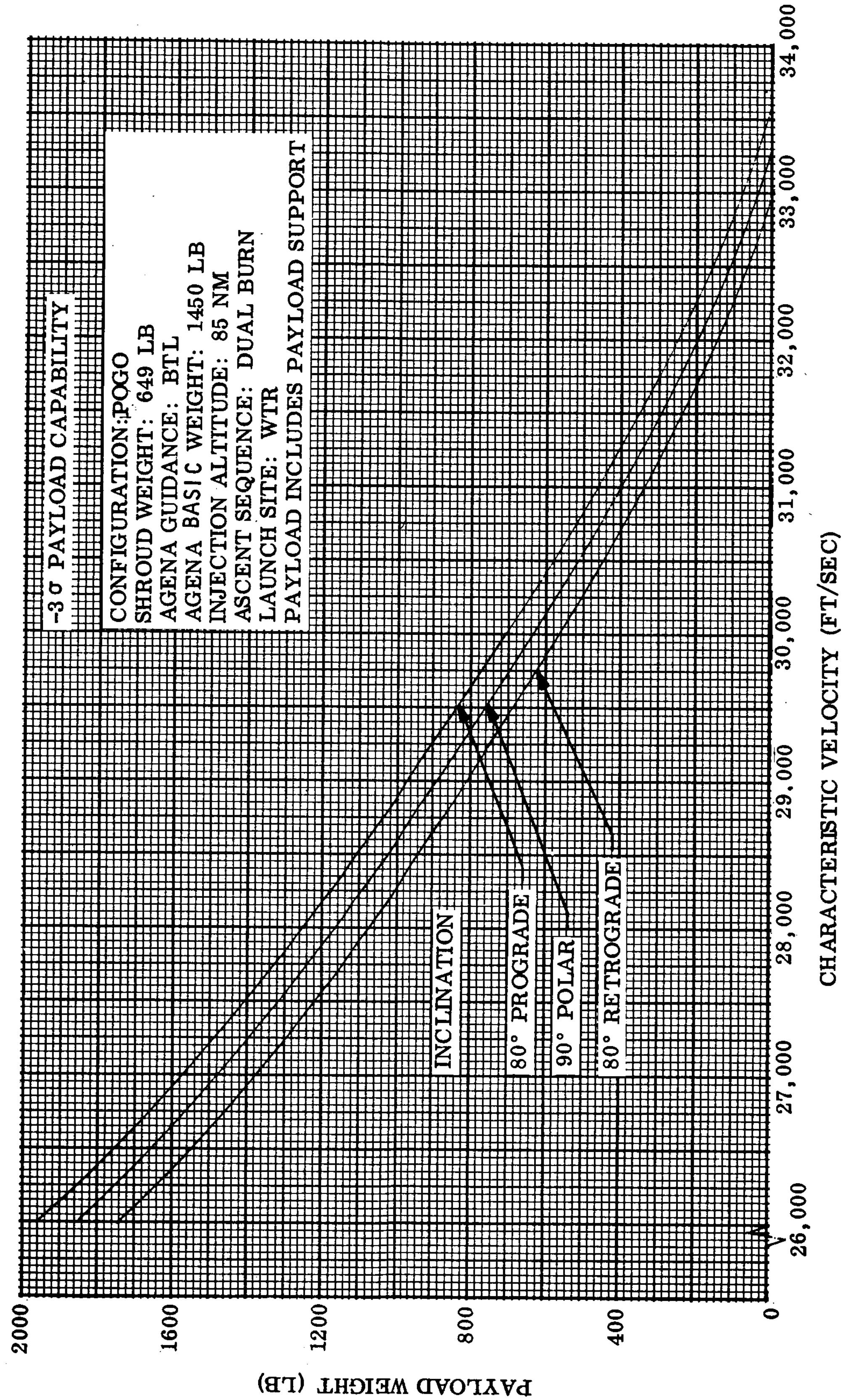


Fig. 2-22 Payload Vs. Characteristic Velocity, POGO Type Equipment

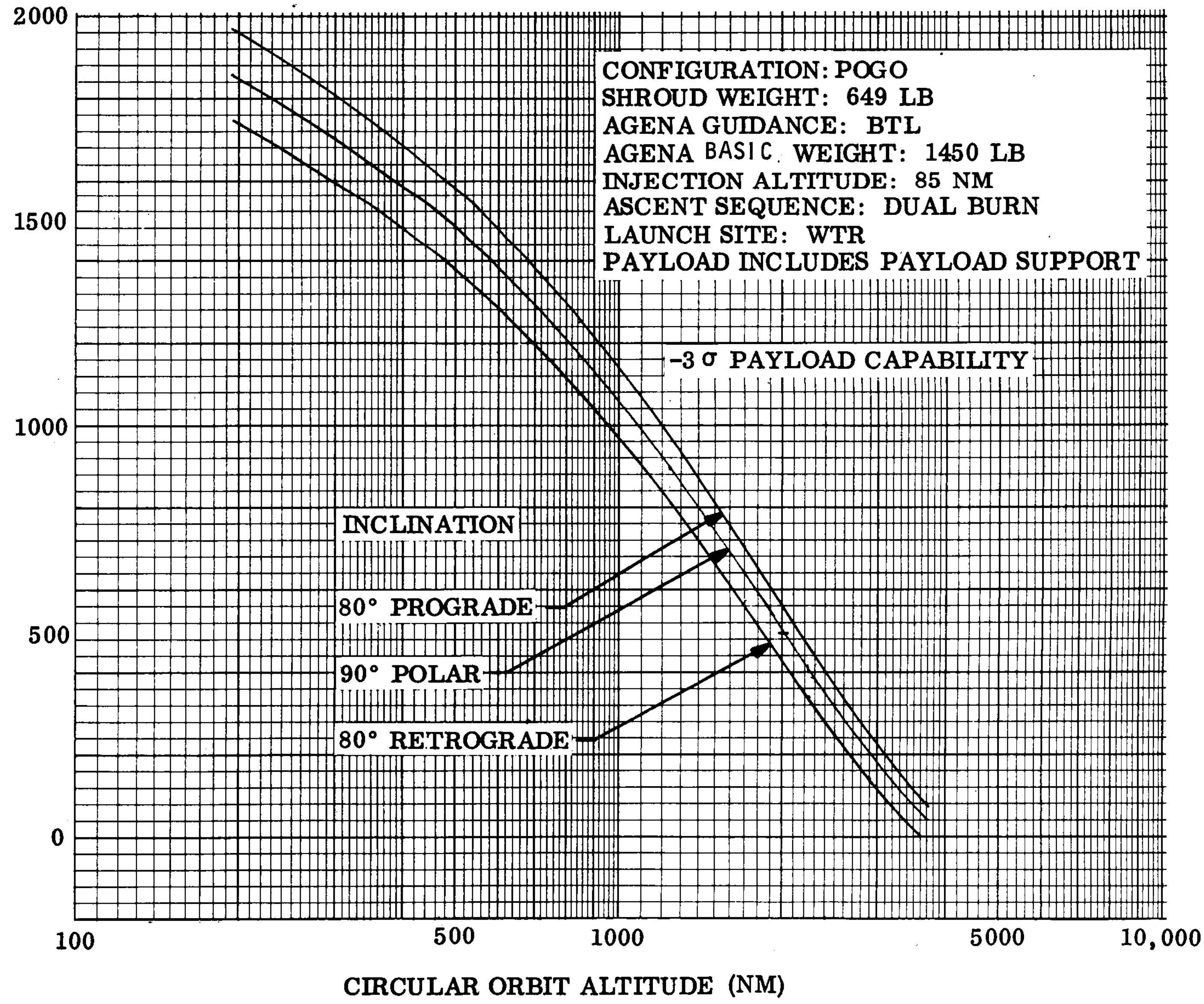


Fig. 2-23 Payload Vs. Circular Orbit Altitude, POGO Type Equipment

E-3236-4

E-3236-4

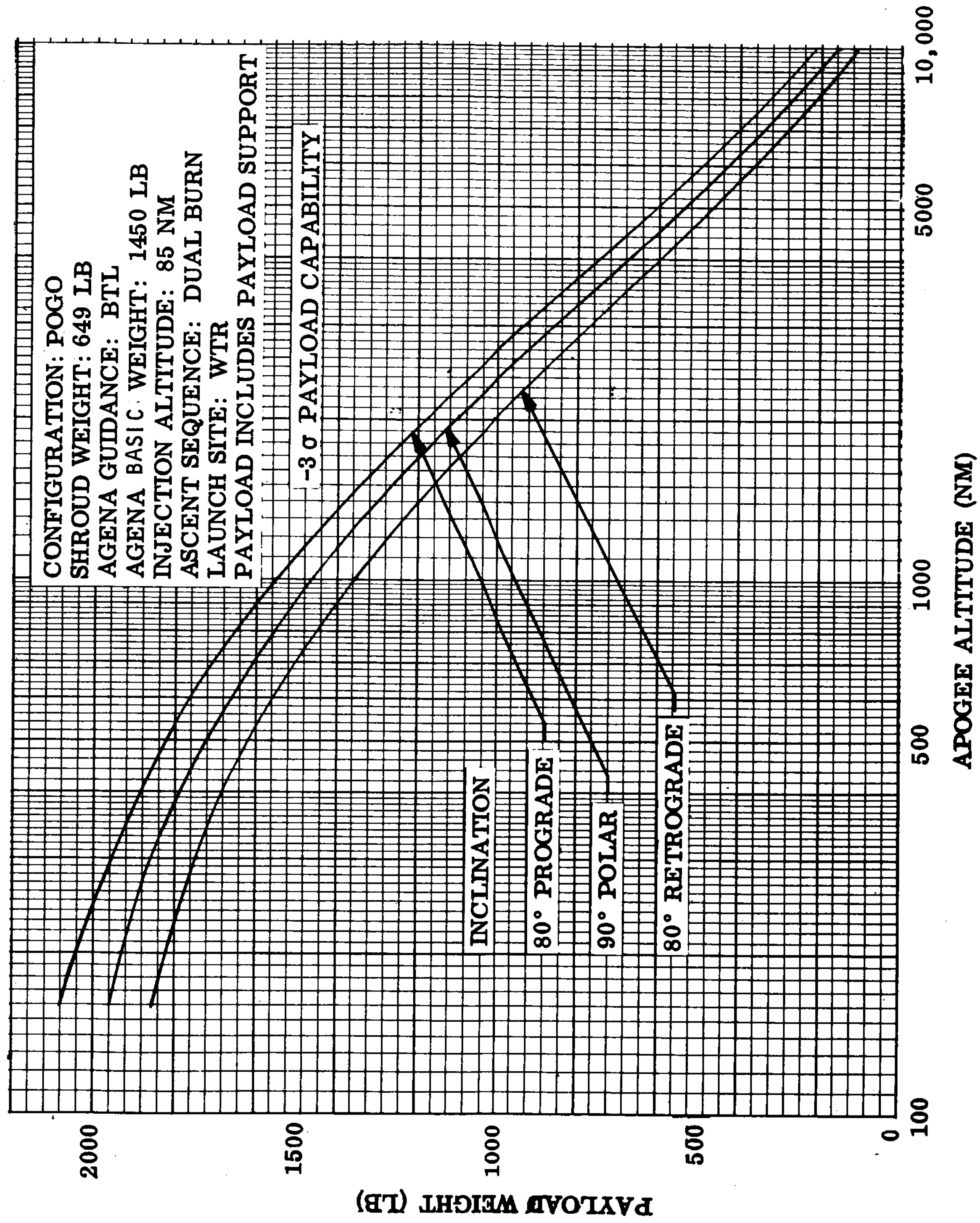


Fig. 2-24 Payload Vs. Elliptical Orbit Apogee, POGO Type Equipment

E-3236-4

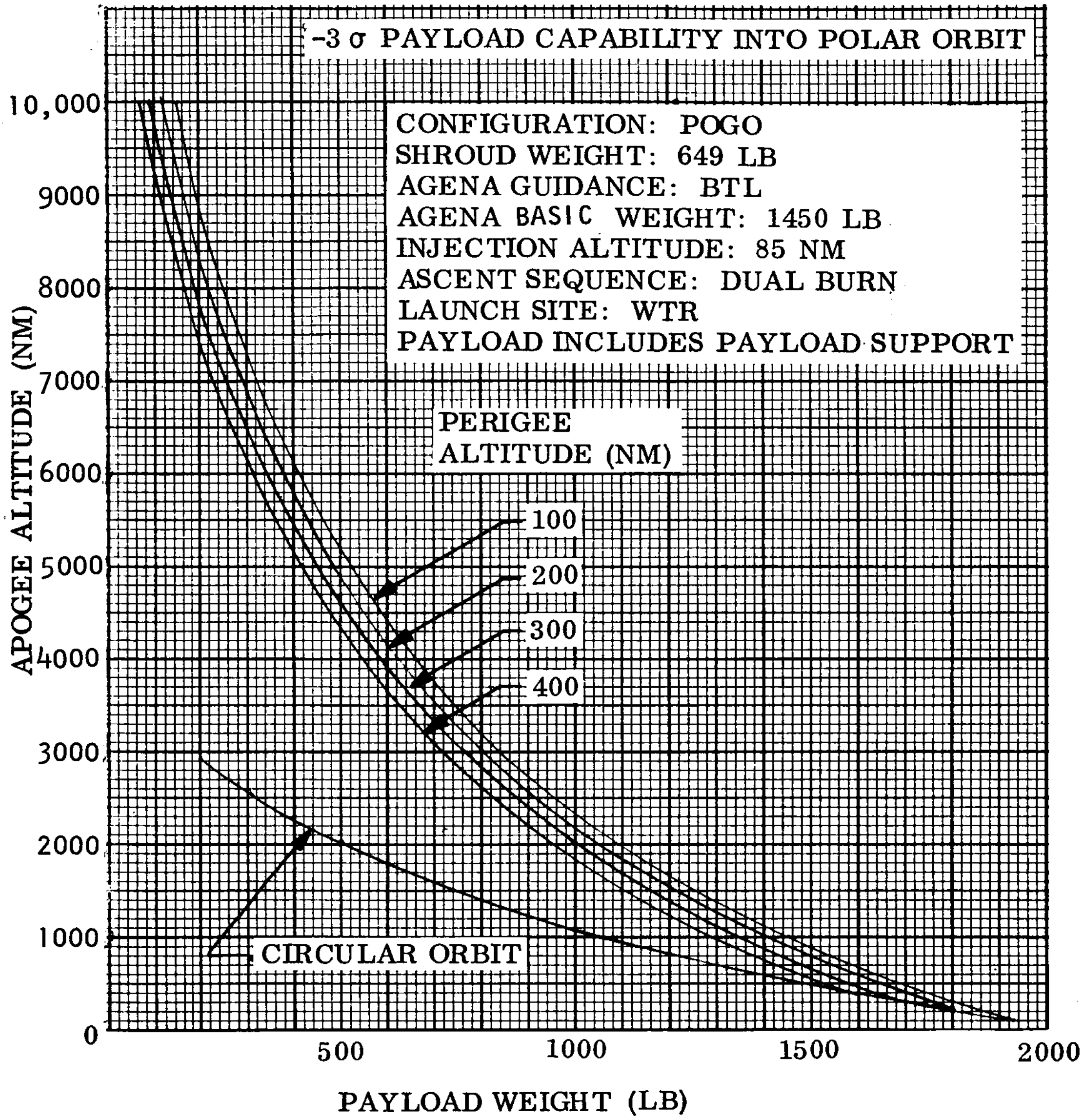


Fig. 2-25 Payload Vs. Apogee Altitude (For Perigee Altitudes of 100, 200, 300, and 400 nm), POGO Type Equipment

E-3236-4

SECTION 3
LAUNCH VEHICLE INJECTION ACCURACY

3.1 GENERAL

This section summarizes the general degree of accuracy with which the booster-Agena launch vehicle system may be expected to accomplish its mission. Because accuracy varies both with the mission and with the choice of launch vehicle configuration, and because a mission error analysis is an expensive undertaking (in computer time), the data presented here is taken from several recent error analyses of particular missions. The selection of examples is intended to indicate generally the overall precision of the booster-Agena launch vehicle. Empirical data from test programs and flight experiences have been used; and since applicable data continue to be generated, quoted values should be taken as a general indication of overall accuracy, rather than as specific values for universal application.

3.2 ERROR SOURCES

Deviations from nominal trajectory of an actual ascent are caused by three kinds of phenomena:

a. Random dispersions in the performance of the individual components of the launch vehicle system, such as gyro drifts, specific impulse variations, etc.

b. Uncertainties in certain launch vehicle characteristics (e.g., drag coefficients)

c. Unpredictable conditions in the environment, such as crosswinds.

Each of these types of error sources contributes to the overall uncertainties in the final injection conditions. The contribution of a particular error source depends on the magnitude of its error and upon the sensitivity of the injection conditions to this error source (see paragraph 3.4). The error sources for the Standard Atlas, Thrust Augmented Thor, and Agena D are shown in Tables 3-1, 3-2, and 3-3 respectively.

Table 3-1

STANDARD ATLAS (SLV-3) ERROR SOURCES AND THEIR DEVIATIONS*

	Parameter	Tolerance (3σ)
1.	Gyro Drift	
	a. Roll	30 deg/hr
	b. Pitch	30 deg/hr
	c. Yaw	30 deg/hr
2.	Decoder Drift	
	a. Pitch	72 deg/hr
	b. Yaw	72 deg/hr
3.	Thrust	
	a. Booster	3000 lb
	b. Sustainer	940 lb
4.	Specific Impulse	
	a. Booster	2.4 sec
	b. Sustainer	3.1 sec
5.	Propellant Loaded	
	a. Fuel	504 lb
	b. Oxidizer	1369 lb
6.	Pitch Program Attenuation	4.6%
7.	Nonpropellant Weights	
	a. Booster Dry	54 lb
	b. Booster Residuals	87 lb
	c. Sustainer Dry	177 lb
	d. Sustainer Residuals	171 lb
8.	Booster Staging Acceleration	0.2g
9.	Propellant Expended During Ground Run	462 lb
10.	Propellant Utilization Uncertainty	295 lb

E-3236-4

*Values subject to change as more test data becomes available.
Lunar Orbiter Performance Analysis, Task No. 18 (U), dated 11 January 1965, LMSC-A654896.

E-3236-4

Table 3.1 (Cont.)

Parameter	Tolerance (3σ)
11. Radar Noise	
a. Velocity Magnitude at VECO	2.3 fps
b. Pitch Velocity at VECO	30.6 fps
c. Yaw Attitude at VECO	0.992 deg*
d. Primary Timer Start Time	0.64 sec
e. Restart Timer Start Time	0.25 sec
12. Drag	10.0%
13. Winds	3σ MSFC wind profile

*Combined effect (e.g., booster thrust alignment, gyro uncaging, etc.)

E-3236-4

Table 3-2

THRUST AUGMENTED THOR (SLV-2A) ERROR SOURCES AND THEIR DEVIATIONS*

Parameter	Tolerance (3σ)
1. Booster I_{sp} (MECO)	2.73 sec
2. Booster Thrust (MECO)	7620 lb
3. Propellant Utilization	400 lb
4. Fuel Loaded	645 lb
5. Oxidizer Loaded	354 lb
6. Shutdown Impulse	
a. Main Engine, Hard Shutdown	5000 lb-sec
b. Main Engine, Soft Shutdown	5000 lb-sec
7. Shutdown Impulse—Vernier Engine	200 lb-sec
8. Booster Dry Weight	66 lb
9. Unusable Fluid and Gases	18 lb
10. Flight Expended Liquid and Gas	8 lb
11. Alignment of Vehicle to Pad (all axes)	0.5 deg
12. Pitch Program Error	3.96%
13. Pitch Gyro Drift	147.1 deg/hr
14. Roll Program Error	3.99%
15. Roll Gyro Drift	
a. Non-g-sensitive	54.3 deg/hr
b. g-sensitive	12 deg/hr/g
16. Yaw Program Error	3.75%
17. Yaw Gyro Drift	129.6 deg/hr
18. Booster Thrust Misalignment (at MECO)	
a. Pitch	0.609 deg
b. Yaw	0.498 deg

*Values subject to change as more test data becomes available.

Nominal Performance and Guidance Parameters and Systems and Component Tolerances for Atlas D, Thor, TAT, Agena B, and Agena D Vehicles, [redacted], dated 15 May 1964, LMSC-A602040.

E-3236-4

Table 3-2 (Cont.)

Parameter	Tolerance (3σ)
19. Booster Auto Pilot Error (at MECO)	
a. Pitch	1.158 deg
b. Yaw	1.089 deg
20. Vernier Auto Pilot Error (at MECO)	
a. Pitch	0.933 deg
b. Yaw	0.633 deg
c. Roll	0.546 deg
21. Misalignment of Agena with Respect to Booster	0.25 deg
22. Solid Motors Case Jettison Timer (One Motor)	1.5%
23. Solid Motor Thrust (One Motor)	2.2%
24. Solid Motor Total Impulse (One Motor)	1.7%
25. Solid Motor Propellant Weight (One Motor)	26.5 lb
26. Solid Motor Case Weight (One Motor)	18.7 lb
27. Control of Thrust Direction	
a. Pitch	1.355 deg
b. Yaw	1.022 deg
28. Radar Noise, Primary Timer Start Time	1.0 sec
29. Radar Noise Velocity Magnitude at (VECO)	3.0 ft/sec
30. Radar Noise Pitch Velocity at (VECO)	12.2 ft/sec
31. Radar Noise Yaw Velocity at (VECO)	9.4 ft/sec
32. Pitch Decoder Drift	Not Specified
33. Yaw Decoder Drift	Not Specified
34. Drag Coefficient	14%
35. Head Winds	100%*
36. Cross Winds	100%*

*100% of wind profile is taken as 3σ deviation.

E-3236-4

Table 3-3

STANDARD AGENA D (SS-01B) ERROR SOURCES AND THEIR DEVIATIONS*

Parameter	Tolerance (3σ)
1. Specific Impulse (Vacuum)	0.6%
2. Thrust (Vacuum)	4.44%
3. Fuel Flow Rate	4.40%
4. Propellant Residuals[1]	27 lb
5. Mixture Ratio	1.94%
6. Propellant Tanking	
a. Single Burn	-283 lb
b. Dual Burn	-283 lb
7. Ignition Time[2]	+.3 sec -.2 sec
8. Vehicle Dry Weight	12 lb
9. Tail-Off Impulse	
a. Normal Closing - Oxidizer Valve	1000 lb-sec
b. Fast Closing - Oxidizer Valve	687 lb-sec
c. Oxidizer Depletion Shutdown	500 lb-sec
10. Thrust Misalignment	
a. Thrust Alignment[3]	0.3 deg
b. Actuator Null Alignment[4]	0.25 deg
c. Lateral Center of Thrust	0.06 in
d. Lateral Center of Gravity	0.30 in
11. Velocity Meter	
a. Bias	2×10^{-4} g
b. Scale Factor Stability[5]	0.01%
c. Altitude Compensation	0.02%
d. Linearity	0.015%

*Values subject to change as more test data becomes available. (Numbered notes are listed after table.)

Nominal Performance and Guidance Parameters and System and Component Tolerances for Atlas D, Thor, TAT, Agena B, and Agena D Vehicles ([redacted]), dated 15 May 1964, LMSC-A602040.

E-3236-4

Table 3-3 (Cont.)

Parameter	Tolerance (3σ)
11. (Cont.)	
d. Linearity	0.015%
e. Alignment	0.1 deg
12. Attitude Programmer	
a. Effect of Power Supply and Interconnect Cabling	2%
b. Gyro Torquer	3%
c. Voltage Divider Tolerance	3%
13. Sequence Timer	
a. Elapsed Time Error	0.02%
b. Repeatability	0.2 sec
14. Pitch and Yaw Gyros	
a. Vibration Sensitive Drift	1.6 deg/hr/g^2
b. Drift at Null	6 deg/hr
c. Drift Off Null	6 deg/hr/deg
15. Roll Gyro	
a. Mass Unbalance, g-sensitive	10 deg/hr/g
b. Vibration Sensitive	4.4 deg/hr/g^2
c. Drift at Null	1 deg/hr
d. Drift Off Null	1 deg/hr/deg
16. Horizon Sensor	
a. Instrument Error	0.3 deg
b. Horizon Noise[6]	0.25 deg

NOTES:
1. Tolerance includes 12 lb. of fuel bias.
2. Time from command signal to 90% thrust attainment.
3. Estimated alignment of actual thrust direction to thrust direction as indicated by alignment tooling.
4. Alignment of null position of engine to thrust direction indicated by tooling.

Table 3-3 (Cont.)

NOTES: 5. Based on one month calibration interval.

6. Detailed analysis of flight data to substantiate the horizon noise value given has not been successful as yet.

E-3236-4

E-3236-4

3.3 METHOD OF CALCULATION

This discussion would be incomplete, and the quoted accuracy values meaningless, without a brief description of how the values are calculated. The calculation is carried out in three steps:

a. Assuming that each error source can be described by a normal distribution, its standard deviation (σ) is calculated from available empirical data, which includes tests of individual components, samples of environmental conditions (e.g., winds), and analyses of flight tests.

b. The dispersions in injection conditions due to each separate error source are computed by substituting 3σ deviations in the error sources, one at a time, into a computer program which simulates the flight of the vehicle, and comparing the resulting injection conditions with those resulting from a nominal flight.

c. The contributions of all the error sources are statistically combined by Monte Carlo method to find the total uncertainty in each injection coordinate.

These steps assume normal variation distribution of each error source, independence of (no correlation between) all error sources, and that the effects of the error sources on the trajectory can be considered linear.*

Injection dispersions may be (and usually are) computed in a downrange-crossrange inertial coordinate system, which is defined by the vehicle's position and velocity at a point near injection into the nominal ascent trajectory. This coordinate system is useful for analysis of the effects of individual error sources.

Orbital accuracies are best specified in terms of uncertainties in the familiar orbit characteristics: period, apogee-perigee difference, and inclination. Values for two missions with each of two booster configurations are shown in Table 3-4, along with values of the injection accuracies in velocity, radius, and flight path angle.

*See "Performance Sensitivities for NASA Agena Missions - Final Report Task No. 10," LMSC-A603407, for detailed description.

E-3236-4

Table 3-4

INJECTION AND ORBITAL ACCURACIES*

Vehicle	Mission (circular orbits)	3σ injection uncertainty V_i (ft/sec)	r (nm)	$\Delta\gamma$ (deg)	3σ orbit uncertainty P (min)	$(r_a - r_p)$ (nm)	i (deg)
Atlas/Agena D	150 nm ETR i = 29° (1 Burn)	10.7	1.33	0.21	0.09	22.3	0.11
	2200 nm WTR Polar (2 Burn)	54.6	18.1	0.21	0.52	34.3	0.36
	5000 nm ETR i = 29° (2 Burn)	24.6	23.2	0.16	1.20	25.4	0.53
	Space Probe ETR Launch Azimuth 90° to 114°	71.7	10.1	0.22	-	-	-
TAT/Agena D with BTL in Agena	150 nm WTR Polar (1 Burn)	23.0	1.50	0.11	0.13	12.0	0.11
TAT/Agena D with BTL in Booster	600 nm WTR i = 81° Retrograde (2 Burn)	71.4	15.1	0.39	0.35	53.5	0.81

V_i = inertial velocity

r = geocentric radius

γ = flight path angle (with respect to local horizontal)

P = orbital period

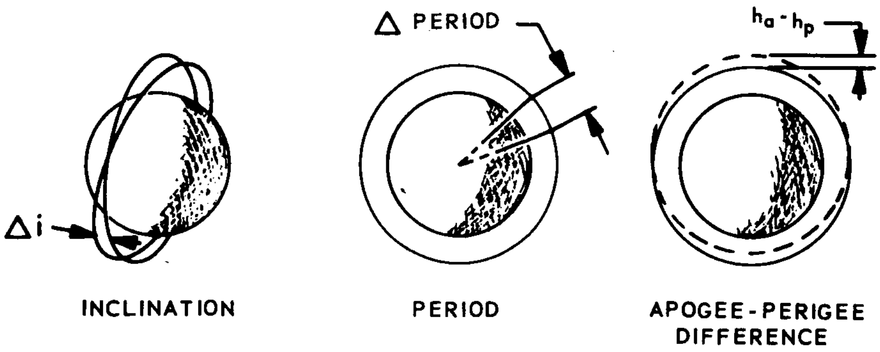
r_a = apogee radius

r_p = perigee radius

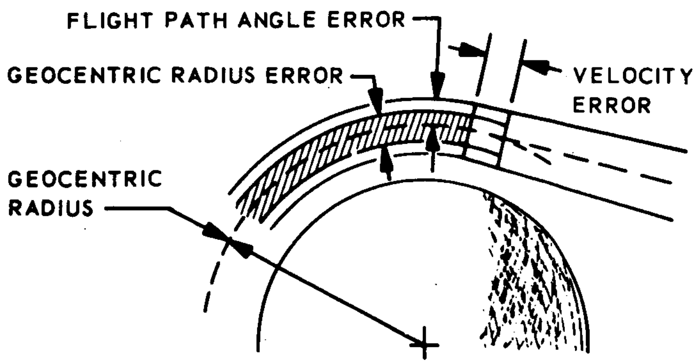
i = inclination angle

*These data are representative values and do not apply directly to any specific mission.

See Fig. 3-1 for earth orbit and probe trajectory error geometry.



EARTH ORBIT ERROR GEOMETRY



PROBE TRAJECTORY ERROR GEOMETRY

Figure 3-1 Earth Orbit and Probe Trajectory Error Geometry

On probe missions (also shown in Table 3-4), even small injection errors cause the probe to diverge significantly from the nominal trajectory. For this reason, a small midcourse correction is usually required at 12 to 15 hours following injection for lunar probes and 7 to 8 days for interplanetary probes.

Since error source data are constantly being updated through testing and flight experience, the values stated should be employed only to provide an indication of booster-Agena capabilities.

3.4 MAJOR CONTRIBUTING ERROR SOURCES

The two effects of vehicle system deviations (not a malfunction) are to disperse the vehicle about the nominal trajectory and (for some specific errors) cause shutdown with excess propellant in the tanks or cause depletion of fuel before reaching the desired end conditions. The margin discussion in paragraph 2.4 describes the compensation made to guarantee commanded shutdown of the engine considering minus three-sigma tolerances of the booster/Agena D system. A margin allowance does not eliminate the vehicle dispersions. For example, dispersions due to Agena attitude errors and tail-off impulse cannot be accounted for by propellant margins.

Table 3-1, 3-2, and 3-3 present a listing of vehicle tolerances typical of the inputs used to generate a dispersion study. These deviations from the nominal values are used to perform accuracy studies for all NASA missions.

Of the error tolerances listed in the aforementioned tables, those contributing to over 90 percent of the injection errors are tabulated for the Atlas-boosted and TAT-boosted vehicles in Table 3-5. The order in which these error sources appear does not necessarily signify the descending order of importance for all missions. Table 3-5 was derived by examining the contributors to injection errors for several missions and selecting the largest. The relative significance for these injection errors varies slightly from mission

E-3236-4

to mission, but for all missions, these errors aptly describe the injection dispersions. Injection deviations in altitude, velocity magnitude, flight path angle and azimuth were used to select the contributing error sources. Orbit parameters were not used in generating Table 3-5 because of their greater dependence on the mission.

The errors are divided into the three major sources of error; the booster, interface, and Agena D. The booster errors include the guidance and environmental errors as well as the booster hardware variations. The interface errors are those caused by referencing Agena initial conditions to booster conditions. Such errors as Agena initial attitude reference (derived from structural alignment, booster attitude errors, and separation transients) and timer start errors are considered interface errors. In general, the booster contributes 10 to 20% of the total error, the interface 20 to 30% and Agena the remaining 50% to 70% for the case where BTL guidance is in the booster only. With BTL guidance in the Agena stage, the resulting errors are greatly reduced, particularly those errors stemming from deviations in yaw control.

Table 3-5

SIGNIFICANT CONTRIBUTORS TO INJECTION DISPERSION

1. Atlas/Agena D

   A. Booster

      Pitch Velocity at VECO (Radar Noise)

   B. Interface

      Timer Start Time
      Yaw Attitude at VECO

   C. Agena

      Pitch Attitude Reference
      Thrust and Flow Rate
      Center of Gravity to Center of Thrust Offsets
      Tail-Off Impulse
      Accelerometer Scale Factor
      Ignition Time
      Pitch Programmer
      Yaw Gyro Drift

2. TAT/Agena D

   A. Booster

      Pitch Drift
      Propellant Utilization
      Winds
      Pitch Program

   B. Interface

      Pitch Attitude at MECO
      Yaw Attitude at MECO

   C. Agena

      Thrust and Flow Rate
      Pitch Program
      Pitcy Gyro Drift
      Velocity Errors
         (Velocity Meter and Tail-off)
      Yaw Gyro Drift
      Radar Noise

E-3236-4

E-3236-4

SECTION 4
RELIABILITY

It is obvious that NASA aspires toward 100 percent reliability in all aspects of launch vehicle performance. However, for purposes of analytical evaluation and apportionment, reliability and confidence numbers are assigned. Therefore, this section summarizes the basic Agena D system and subsystem reliabilities for a typical ascent mission. The Agena D has a design requirement of 90 percent reliability at 75 percent confidence in performing primary flight objectives during ascent and spacecraft injection into orbit. The reliability goal is an ascent flight success ratio of 94 percent. Demonstrated reliability is 97 percent at 50 percent confidence for the last 25 flights.

The summary of basic Agena system reliability includes reliability estimates for each major subsystem. The reliability estimates presented are based on flight data, ground test data, reliability analyses, and the application of individual components. The data given may be used as a general guide in the selection of particular hardware combinations which are required to meet specific ascent mission objectives. The system and subsystem reliabilities of the Mariner Mars mission are presented to indicate how program peculiar/optional hardware affect over-all mission reliability. For detailed discussion of the Agena and its associated equipment refer to Parts III, IV, and V of this catalog.

4.1 BASIC VEHICLE RELIABILITY ESTIMATES

The basic vehicle consists of hardware which is common to approximately 80 percent of current LMSC space programs. By itself, the basic vehicle is not flyable; flight capability is achieved by installing a selection of fully qualified optional equipment and adding a first-stage booster.

It should be emphasized that all subsystems are subject to modification by the using program and that certain standard Agena equipment may be removed and other program peculiar and/or optional flight hardware added to meet the configuration requirements of specific missions.

As an aid in program planning, reliability estimates for communication and control equipment (subsystem C&C) provided by the basic vehicle, have been included in the derivation of basic vehicle subsystem estimates. Although the SS/C&C hardware provided by the basic vehicle includes some necessary elements for building program peculiar telemeter and command systems, the basic hardware would never be flown without additional program peculiar equipment. Table 4-1 summarizes basic hardware reliability for ascent by subsystem.

E-3236-4

Table 4-1
BASIC VEHICLE ASCENT RELIABILITY

Subsystem	Function	Reliability
A	Structures	.997
B	Propulsion	.985 (1) .983 (2)
C	Electrical Power	.999
D	Guidance & Control	.994
C&C	Communications & Control	.999
	TOTAL BASIC VEHICLE RELIABILITY	.974 (1) .972 (2)

Note: Table 4-1 was obtained from data in Table 1-1 of SS-01B Reliability Estimate Report (U), LMSC-A745391, 16 June 1965, (Confidential) submitted under Contract AF 04(695)-695.

(1) With Model 8096 Rocket Engine (Dual or Single Start Basic)

(2) With Model 8247 Multiple Restart Rocket Engine

E-3236-4

4.2 MARINER MARS SYSTEM RELIABILITY ESTIMATES

Selected as a typical ascent mission, the Mariner Mars ascent mission objectives are as follows:

a. <u>Primary</u>

- Provide required environmental protection for spacecraft
- Eject nose fairing properly
- Achieve proper separation from booster adapter
- Achieve required parking orbit within specified tolerances
- Achieve required final injection parameters within specified tolerances
- Eject spacecraft properly

b. <u>Secondary</u>

- Obtain environmental and functional telemetry data

Subsystem C&C functions are considered to fulfill the secondary mission objective. Therefore, reliable operation of this subsystem is considered highly desirable but not essential to mission success. Mariner Mars system reliability is indicated in Fig. 4-1. The series arrangement shown in the block diagram indicates that a failure of any one block results in mission failure and therefore the vehicle reliability is the product of all the blocks.

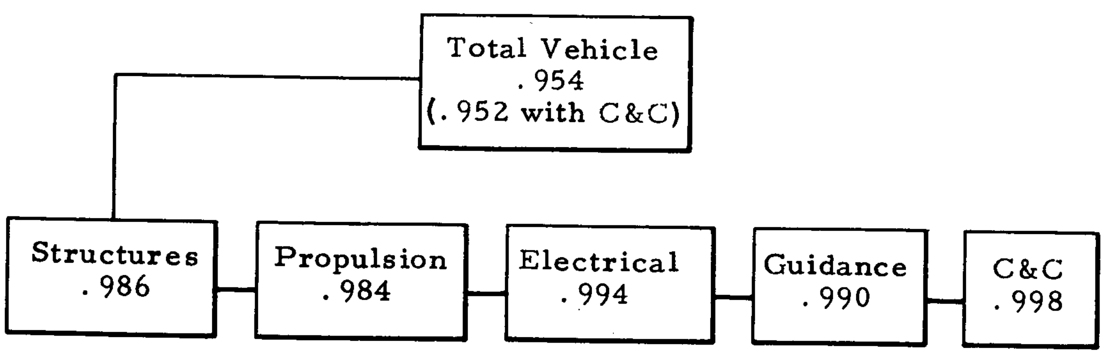


Figure 4-1 Mariner Mars Agena Vehicle Reliability*

*Ref. LMSC-A731805, Final Product Assurance Report for Mariner Mars Vehicles 6931, 6932, dated 5 February 1965

E-3236-4

4.2.1 Subsystem A (Structures)

For reliability estimating, subsystem A is considered to include not only the airframe (and the miscellaneous structural members), but also some subsystem D equipment such as the pyrotechnically operated pin-pullers and pin-pushers used in the horizon sensor fairing jettison and the horizon sensor positioning. Other pyrotechnic devices in subsystem A include those used in the shroud and spacecraft separation systems, and the primacord system (detonator and charge) used for booster adapter separation. The over-the-nose (OTN) shroud and booster adapter extension kit, both program peculiar items, are included in subsystem A. (For a discussion of shroud and separation reliability estimates, refer to par. 4. 3. 1) The reliability block diagram for subsystem A is given in Fig. 4-2. . All equipment is depicted in series arrangement, and the subsystem reliability is the product of the reliabilities indicated in all the blocks.

4.2.2 Subsystem B (Propulsion)

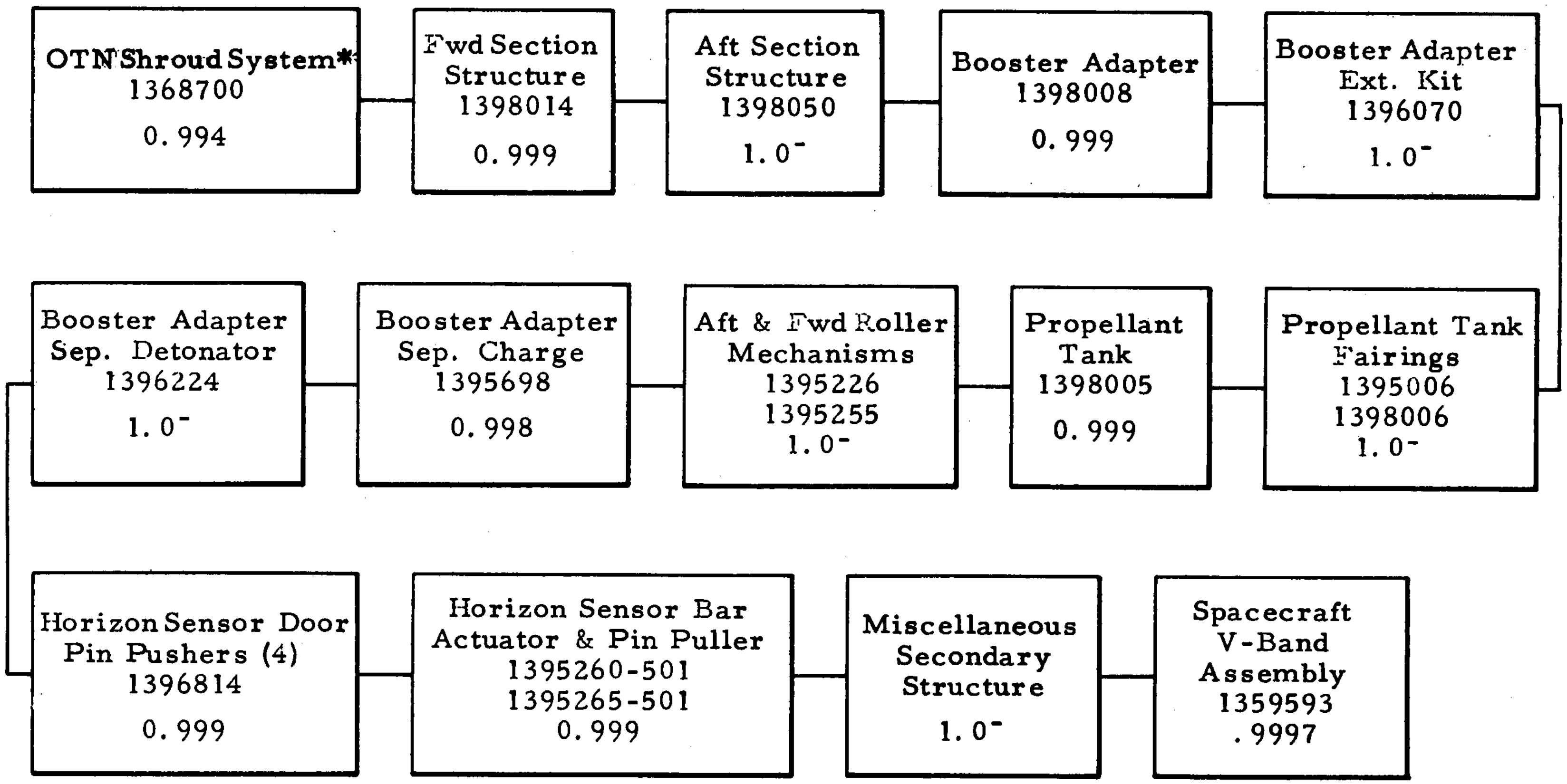
The propulsion subsystem provides the Agena vehicle with the second-stage velocity increment required to reach parking orbit. This parking orbit phase is then followed by a second burn during which the Agena establishes the proper trajectory. After completion of second burn, the spacecraft is ejected.

The reliability block diagram for this subsystem, Fig. 4-3, show all the blocks in series except for the two retrorockets* shown in parallel. The two retrorockets are considered as redundant equipment since operation of either one will satisfactorily accomplish ejection of the booster adapter from the Agena.

4.2.3 Subsystem C (Electrical Power)

The electrical power subsystem supplies all of the power at the operating voltages required by the Agena during flight.

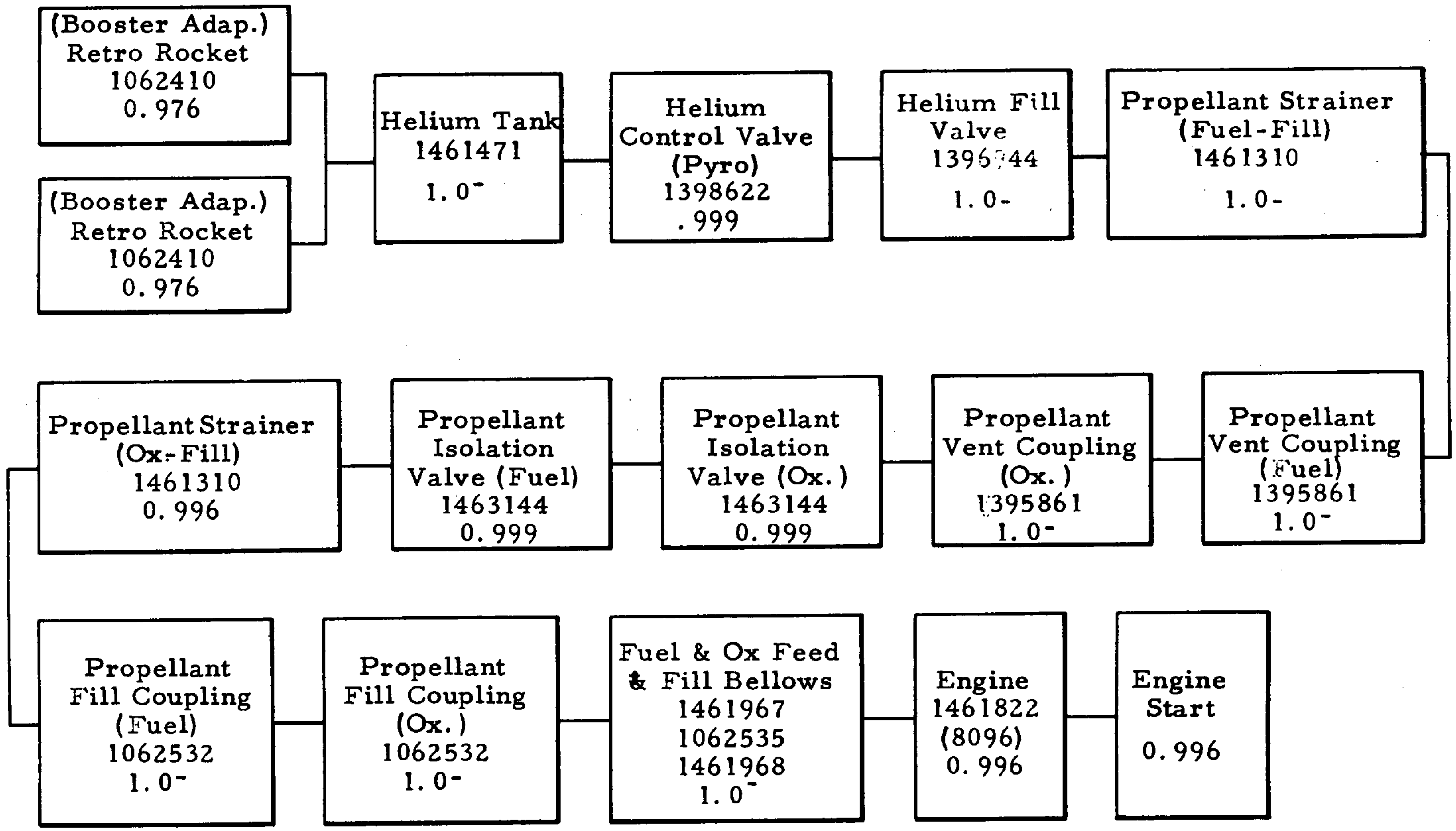
*Located on the booster adapter for booster separation.



*Includes Explosive Bolts and Hardware

1.0^{-} = .9999 or greater
R = 0.986

Figure 4-2 Reliability Block Diagram for Subsystem A, Structures



Note: All items Basic SS-01B Equipment

1.0^{-} = .9999 or greater

R = 0.984

Figure 4-3 Reliability Block Diagram, Subsystem B (Propulsion)

The reliability block diagram for this subsystem, Fig. 4-4, shows all of the blocks in series except for the two DC relays shown in parallel. The two relays are a part of the shroud separation system which have redundant features.

4.2.4 Subsystem D (Guidance and Control)

The guidance and control subsystem provides the timing, sequencing, velocity sensing, guidance and attitude control required by the Agena during powered flight and orbit. All equipments are not functioning all the time, for instance the hydraulics system operates only during main engine burn, the nitrogen system operates only during orbit. However, since all are generally required for mission success, they are all depicted in series. The reliability block diagram for this subsystem is Fig. 4-5.

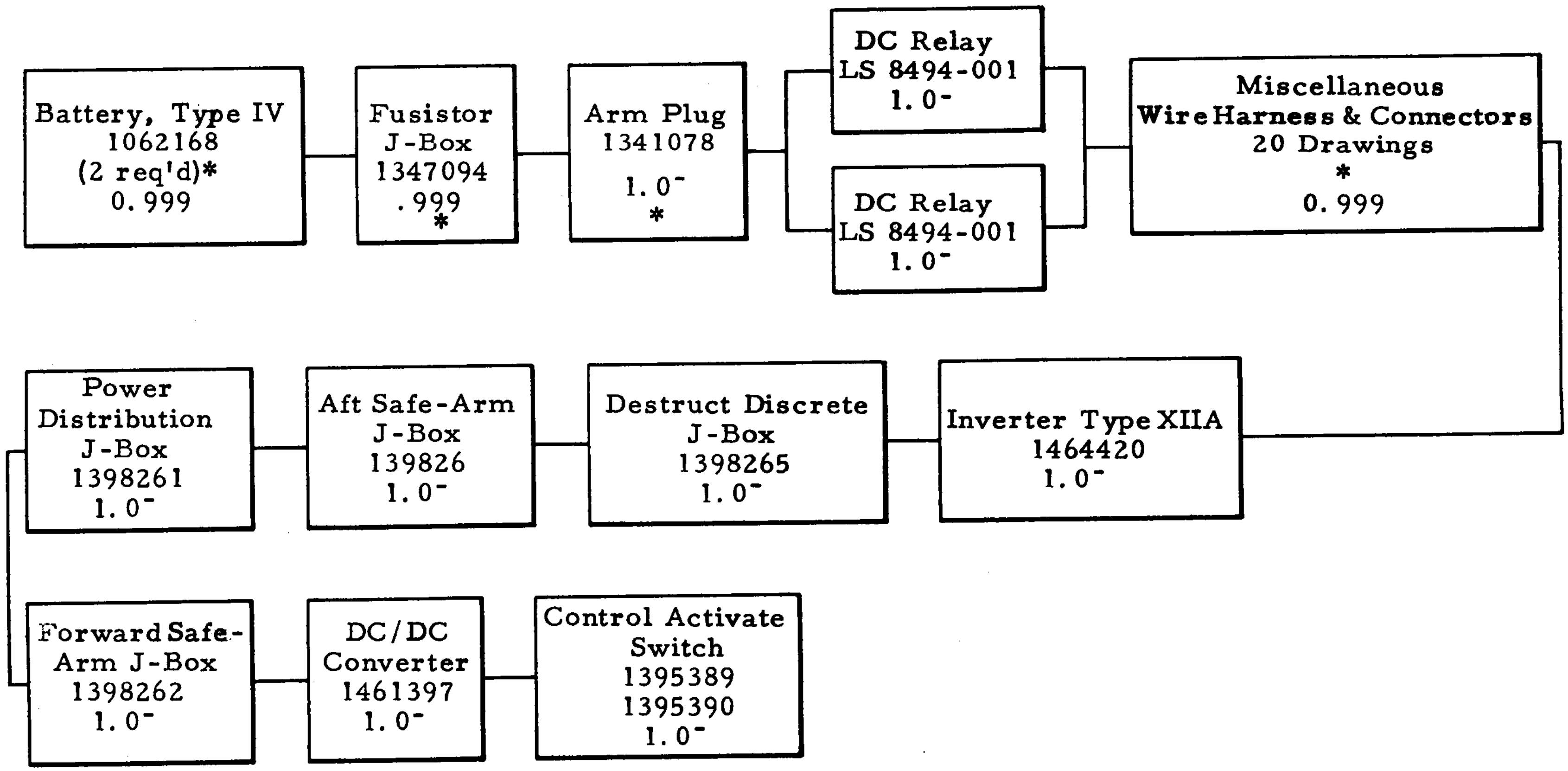
4.2.5 Subsystem C&C (Communication & Control)

The C&C subsystem provides the capability for measuring or monitoring environmental and functional conditions in the Agena, telemetering data to ground stations, and furnishing tracking signals in response to radar interrogation. In general, this subsystem is composed of an FM/FM telemeter with antenna and a C-band beacon transponder with antenna. The reliability estimates for the C&C subsystem are based on operation commencing one hour prior to launch. The reliability block diagram for C&C, Fig. 4-6, includes three separate independent systems (telemetry, tracking, and destruct).

4.3 SEPARATION RELIABILITY ESTIMATES

4.3.1 Shroud System

The over-the-nose shroud is attached to the vehicle by a V-band held together by two pyrotechnic bolts. The pyrotechnic bolts each have two squibs and will break if either of the squibs operate. The V-band will separate with

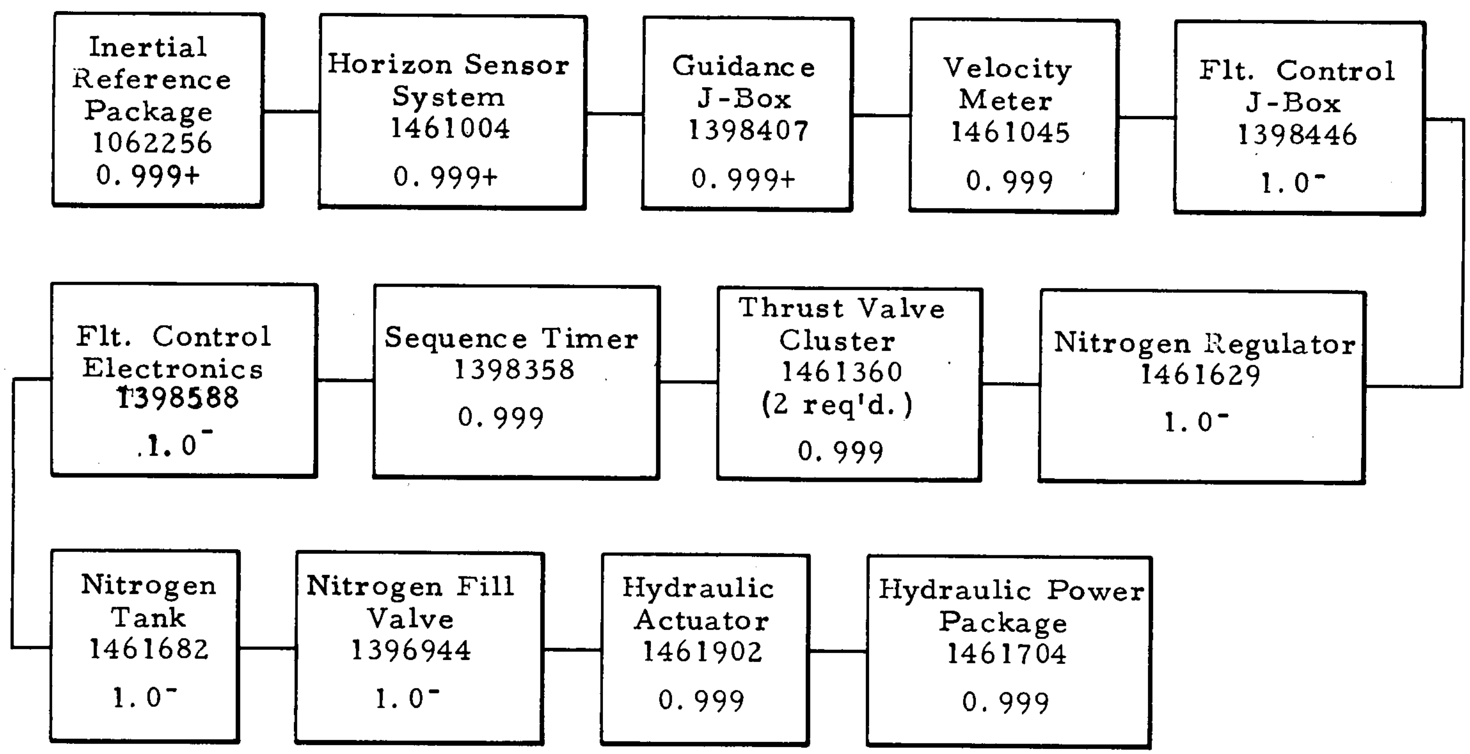


* Indicates Optional/Program Peculiar Items

R = 0.994
1.0 = .9999 or greater

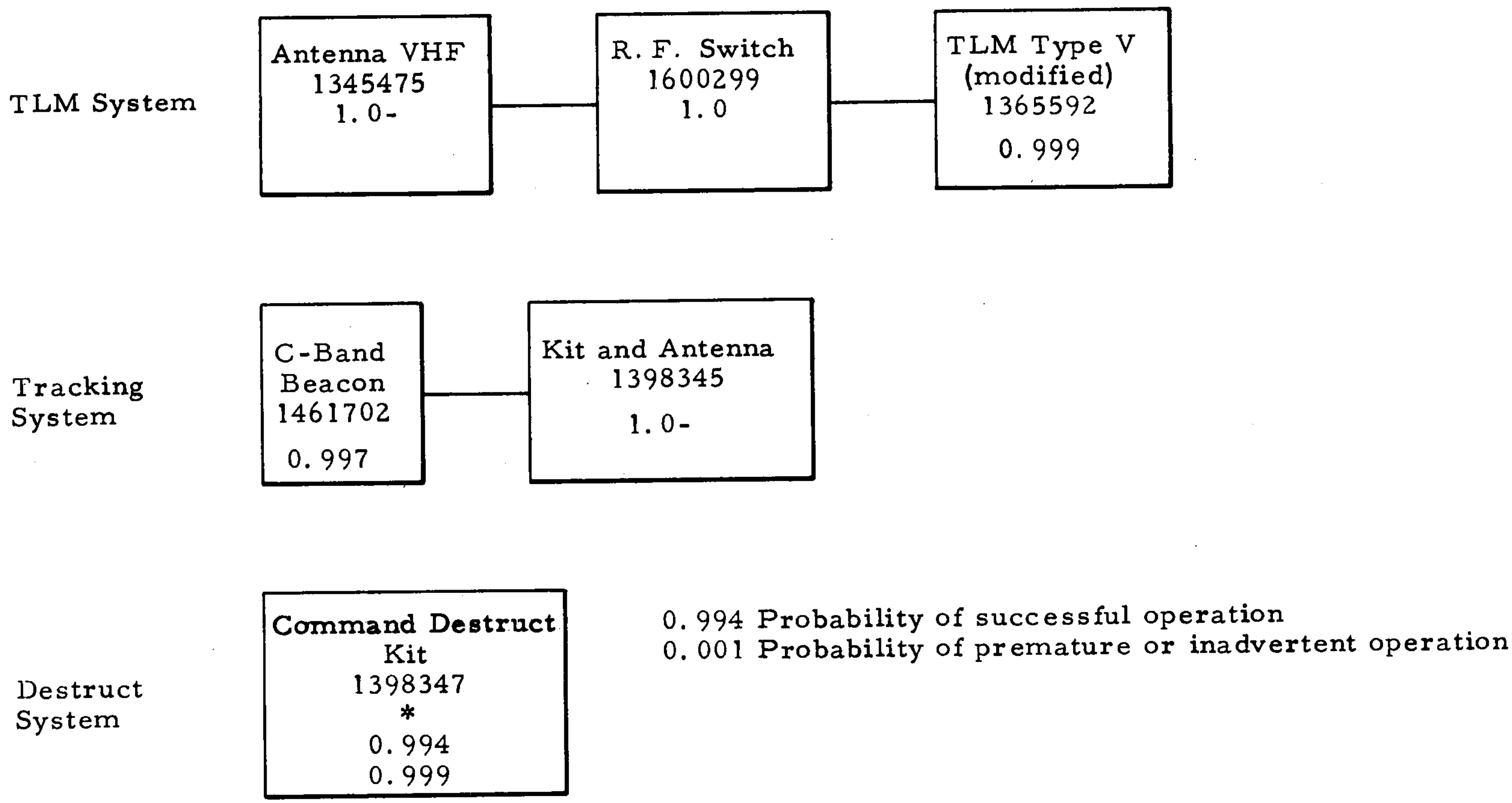
Fig. 4-4 Reliability Block Diagram, Subsystem C (Electrical)

E-3236-4



R = 0.990
1.0^- = .9999 or greater

Figure 4-5 Reliability Block Diagram, Subsystem D (Guidance and Control)



* Indicates Optional/Program Peculiar Items
R = 0.998 (Total C&C)

Figure 4-6 Reliability Block Diagram, C&C Subsystem (Communications and Control) breakage of one or both bolts, and upon separation of the V-band, pre-loaded spring assemblies will eject the shroud. The inherent reliability of the shroud ejection system including spring mechanisms and band separation, is calculated to be 0.994.

E-3236-4

4.3.2 Spacecraft Separation System

The Mariner spacecraft is mounted in place by a V-band tensioned to 2,500 pounds. This V-band is pyrotechnically separated at two points in the same manner as the shroud V-band. When the spacecraft V-band separates, the spacecraft is ejected from the spacecraft adapter and Agena vehicle by means of pre-loading springs. The probability of successful completion of spacecraft separation is 0.992.

4.3.3 Booster Separation

Booster separation is accomplished by firing a separation detonator and charge which severs the booster adapter from the Agena. The Agena then moves out of the adapter by means of the roller mechanism. Two retro-rockets mounted in the adapter provide separation thrust. The adapter is jettisoned with the booster. The estimated reliability for separation is 0.997.